

1  
AD733387

THE DEFENSE OF ANTWERP AGAINST THE V-1 MISSILE

A thesis presented to the Faculty of the U.S. Army  
Command and General Staff College in partial  
fulfillment of the requirements of the  
degree

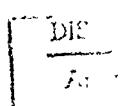
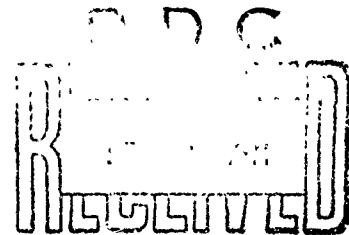
MASTER OF MILITARY ART AND SCIENCE

by

R. J. BACKUS, LTC, USA  
B.S., Southern Colorado State College, 1965

Reproduced by  
NATIONAL TECHNICAL  
INFORMATION SERVICE  
Springfield, Va 22151

Fort Leavenworth, Kansas  
1971



THESIS APPROVAL PAGE

Name of Candidate R. J. BACKUS, LTC, USA

Title of Thesis THE DEFENSE OF ANTWERP AGAINST THE V-1 MISSILE

Approved by:

Donald J. Alancy, Research and Thesis Advisor

Charles W. Hurd, Member, Graduate Research Faculty

Robert D. Lingle, Member, Graduate Research Faculty

Ralph C. Walker, Member, Consulting Faculty

David E. Shugard, Member, Consulting Faculty

Date: 15 June 1971

The opinions and conclusions expressed herein are those of the individual student author and do not necessarily represent the views of either the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

## ABSTRACT

This thesis is an incomplete historical investigation of the World War II Allied defense of Antwerp, Belgium, against the German V-1 pilotless aircraft. The purpose is to establish the reasons for the defense's success and failure thru an analysis of the defense in terms of the air defense engagement functions: detection, identification, interception and destruction.

The V-1 missile originated in 1907 with the initial conception of a pulse-jet engine and culminated with test firings in the winter of 1942-43. The V-1's range was about 150 miles and it carried over 1,900 pounds of high explosives in its warhead.

The Germans initially employed the V-1 from launch sites in France aiming them at London. The British were prepared and after a shake-down period they established a formidable defense.

The Allied invasion of the European continent and subsequent geographic gains caused a temporary lull in attacks against London. Logistical problems occurring on the continent threatened to halt offensive operations until the British 21 Army Group overran the port of Antwerp. This port promised to be a solution to the mounting supply difficulties. The Germans recognized Antwerp's significance to future Allied operations and took action to attack the city with the V-1 missile.

The Allies realized the German intent and established a defense primarily composed of U. S. antiaircraft units. The London experience had demonstrated the value of antiaircraft artillery and exposed the

weaknesses of a defense employing fighter aircraft.

The V-1 attacks began in October 1944 and ended in March 1945. During this time 4,883 V-1's were detected by the defense. More than 2,500 V-1's were designated as vital area threats. The defense destroyed over 70 per cent of these. Only 211 landed within the designated vital area.

Detection was accomplished with a high degree of success. This is attributable to the characteristics of the V-1. It followed a constant heading at a constant speed and altitude. The defense was deployed accordingly.

The V-1 characteristics greatly simplified the identification problem. Visually the V-1 was readily identified during all hours of the day. Its flight characteristics made it immediately suspect to detection radar operators. Close control of Allied aircraft operating in the area helped the identification process.

Interception and destruction are inseparable for analysis purposes. The SCR-584 radar combined with the 90mm or 3.7 inch gun using proximity fused projectiles proved to be very effective against the V-1. The 40mm guns employed by both U. S. and British units were relatively ineffective due primarily to the ruggedness of the V-1 and the small explosive charge of the 40mm projectile.

The success of the Antwerp defense was unmatched during World War II. Interception was the least perfected of the four engagement functions.

## TABLE OF CONTENTS

	Page
LIST OF TABLES .....	vii
LIST OF FIGURES .....	viii
Chapter	
INTRODUCTION .....	1
I. THE THREAT .....	3
BACKGROUND .....	3
CHARACTERISTICS .....	8
BRITISH V-1 EXPERIENCE .....	12
LONDON DEFENSE .....	15
II. THE DEFENDED AREA .....	22
SIGNIFICANCE OF ANTWERP .....	22
DESCRIPTION .....	27
GERMAN REACTION .....	29
III. THE DEFENSE .....	33
DEFENSE PHASES AND UNIT DEPLOYMENTS .....	33
ORGANIZATIONS .....	40
EQUIPMENT .....	46
EARLY WARNING .....	52
IV. RESULTS AND ANALYSIS .....	56
DETECTION .....	56

ChapterPage

<b>IDENTIFICATION .....</b>	<b>61</b>
<b>INTERCEPTION AND DESTRUCTION .....</b>	<b>65</b>
<b>V. SUMMARY AND CONCLUSIONS .....</b>	<b>76</b>
<b>BIBLIOGRAPHY .....</b>	<b>83</b>

**LIST OF TABLES**

<b>Table</b>	<b>Page</b>
I. Damage Incidence by Category of Facility Period June 13 to September 5, 1944 .....	14

## LIST OF FIGURES

Figure	Page
1. The Initial London Defense Through July 16, 1944 .....	16
2. The Revised London Defense After July 16, 1944 .....	19
3. Limits of the Vital Area .....	35
4. Origin of V-1 Attacks .....	37
5. Deployment of Units on December 15, 1944 .....	38
6. Deployment of Units on January 27, 1945 .....	39
7. Deployment of Units on March 30, 1945 .....	41
8. Lead Angle and Quadrant Elevation .....	43
9. U. S. Antiaircraft Organizational Structure .....	47
10. British Antiaircraft Organizational Structure .....	48
11. Early Warning Elements and Communications Links .....	55
12. V-1's Destroyed of V-1's Engaged Versus Time .....	69
13. Ammunition Expenditure Versus Time .....	71
14. VA Threats Engaged of VA Threats Detected Versus Time .....	73

## INTRODUCTION

The successful defense of the port of Antwerp, Belgium, by U. S. Army antiaircraft artillery units against the vaunted German V-1 missile is generally regarded as unsurpassed during World War II. The attrition percentage achieved by the Antwerp defenders was over twice as great as attained by other typical World War II antiaircraft defenders. The small number of V-1's which landed in the defended port area and the relatively insignificant amount of damage inflicted is evidence of the success.

The purpose of this thesis is to provide a clearer understanding of the reasons for this victory. The defensive techniques used, the equipment employed and the characteristics of the V-1 will be analyzed in terms of the air defense engagement functions: detection of potential threat objects; identification of unknown objects; interception of enemy forces; and destruction of the threat.<sup>1</sup>

Since the potential threat and characteristics of the German V-1 robot missile were directly related to each of the functions a chapter is devoted to background information about the V-1. A chronological sequence of events is presented ending with the British V-1 defense of London. This defense is explained to provide a basis for later comparison, to develop an appreciation of the defensive problems to be overcome later at Antwerp and to present the origin of

---

<sup>1</sup>The U. S. Department of the Army, Field Manual 44-1: U. S. Army Air Defense Artillery Employment, (Washington: U. S. Government Printing Office, February 1970), p. 2-2.

defensive techniques used in the defense of Antwerp. The physical characteristics of the V-1 are given to provide background for subsequent evaluation.

The second chapter establishes the significance of Antwerp to the Allied war effort. The logistical situation existing on the European continent at the time Antwerp was captured is developed. This chapter provides the "why" for the defense and gives some insight into the urgency and priorities given to the defense.

Chapter III is devoted to the characteristics of the defense. The layout of the defense is examined relative to time. Since both British and U. S. forces were used in the defense the organizations of the antiaircraft elements of both countries are presented. Major items of equipment are discussed briefly to fix defensive equipment capabilities relative to the threat. Early warning of approaching threats had a direct impact on engagement results. Accordingly a brief description of the warning network is provided.

The results of the defense are given in the succeeding chapter. These are analyzed in terms of each engagement function. Where statistical data for analysis is unavailable a qualitative assessment is made of various considerations relative to the overall defense performance.

Chapter V presents a summary and conclusions based on the analysis made in the preceding chapter.

## CHAPTER I

### THE THREAT

Any historical analysis of a military operation requires an understanding of the nature of the threat to be overcome. Physical characteristics of the pilotless aircraft are presented in this chapter to establish a mental picture of the target of the defense. V-1 employment peculiarities were key factors in organizing the Antwerp defense. The evolution of the threat and the events leading up to the defense of Antwerp provide a foundation upon which comparisons can be based in this analysis.

### BACKGROUND

Indiscriminate destruction during war has been a controversial issue throughout the history of warfare. During World War I Germany torpedoed merchant ships taking the lives of crews and passengers formerly considered non-combatants and consequently entitled to protection. With the advent of high altitude bombing, particularly at night, the concept of protection for innocent civilians was forgotten. British area attacks on German cities in the autumn of 1940 and the German "Blitz" gave little thought to physical security for non-combatants.

On June 13, 1944, a new type of indiscriminate offensive bombardment commenced. A small unmanned aircraft was launched from France toward London on that day beginning a new phase of the German reign of

destruction on London.<sup>1</sup> Actually this was only the implementation phase of a long series of events beginning in 1907.

In 1907 A french patent was issued for a pulse-jet using a low-pressure supercharger to pump an air-fuel mixture into a combustion chamber where it was ignited by a "sparkling-plug". Three years later a Belgian engineer patented a series of jet engines which he proposed for use in aeroplanes and airships. In 1919 a French artillery officer proposed jet powered remotely-controlled pilotless aircraft as a long range bombardment weapon. For the next decade further interest in jet propulsion seemed to have centered around a possible replacement for the piston engine in fighter aircraft. Work on pilotless aircraft was carried on by the British and the Germans but little thought was given to a jet propelled pilotless aircraft. Then in the mid-thirties a German inventor suggested a flying torpedo propelled by a jet engine of his own design. Response to his proposal was disappointing.<sup>2</sup>

In the summer of 1939 the German Air Ministry solicited proposals for a pilotless missile with a 350 mile range. One proposal submitted was for a remotely-controlled missile with either a conventional or turbo-jet engine. Apparently other projects demanded a higher priority and the pilotless missile remained only a proposal until the spring of 1942. Beginning in April 1942 massive air raids were conducted on English cities in retaliation for British fire bombings of Lubeck.<sup>3</sup>

---

<sup>1</sup>General Sir Frederick Pile, Ack-Ack (London: George G. Harrap & Co., 1949), p. 326.

<sup>2</sup>Basil Collier, The Battle of the V-Weapons 1944-45 (New York: William Morrow & Co., 1963), pp. 12-14.

<sup>3</sup>Ibid., pp. 14-15, citing Führer Headquarters Signal No. 55 672/42 dated April 14, 1942.

Success of the German raids was disappointing and costly in planes and crews. At this time the sponsors of the 1939 proposal contacted the German Air Ministry to rejuvenate their pilotless aircraft proposal. This time the response was favorable and design work began.

In June 1942 representatives of the developmental firms met at the Air Ministry to discuss the future of the project. The project was outlined and a sketch was drawn of the proposed weapon. At the conclusion of the meeting the missile was given the highest priority for development and production.<sup>4</sup> The experts hoped to have the missile in operation within 18 months but in reality it was almost two years before the first offensive with the new weapon began.

The official German designations for the pilotless aircraft were FZG 76 and 8-103. The German Ministry of Propaganda referred to the weapon as Vengeance Weapon Number One or simply V-1. The Allies referred to the weapon as V-1, Flying Bomb, Diver, Buzz Bomb, Doodle Bug and Pilotless Aircraft (PAC).<sup>5</sup> Throughout the remainder of this paper the designation "V-1" will be used.

Early in December 1942 airframe tests of the V-1 were made and later in the same month the first ground launching was conducted. By the summer of 1943 preparations had been made to begin quantity production of the missile.

On August 17, 1943, the British responded to the German developmental efforts. Nearly 600 aircraft bombed the V-1 experimental test

---

<sup>4</sup> Ibid., p. 17.

<sup>5</sup> Headquarters United States Forces European Theater, Report of the General Board, Study 38, p. 38. (USA C & CSC Archives) Hereafter this Headquarters is cited as USFET.

facilities at Peenemunde on the Baltic Sea. The resulting damage was so severe that the Germans shifted some of their experimental facilities to Poland.<sup>6</sup> Other bombing raids on component factories took their toll and production was delayed until September. By this time missile launch sites had been selected in France and a unit had been trained for the task of launching the V-1 at Britain.<sup>7</sup>

The launch sites consisted of a number of concrete buildings including one structure adjacent to a rectangular concrete slab. The latter appeared to photo interpreters to be a final assembly building for the missile. It was characterized by a 22 foot opening on one side large enough to allow a fully assembled missile to be moved in and out. Other buildings common to all sites were workshops and storage facilities about 260 feet by 10 feet and curved at one end. Viewed from overhead they looked like giant skis laid on their sides.<sup>8</sup>

In December 1943 changes were made in the German command structure responsible for the overall V-1 program. As with any shake-up in command structure the new leaders investigated the entire program. Among the weaknesses, they found that the launch facilities were built physically insecure and highly vulnerable to bombing attacks. Aerial reconnaissance could easily recognize the launch facilities. The new commander recommended that the whole program be overhauled to include abandonment of existing launch facilities in favor of simpler and less distinctive sites.<sup>9</sup>

The Germans revised their plans and began constructing additional

---

<sup>6</sup> Collier, op. cit., p. 33.

<sup>7</sup> Ibid., pp. 18-20.

<sup>8</sup> Ibid., p. 37.

<sup>9</sup> Ibid., pp. 20-22.

sites. The altered sites omitted the ski-type buildings and usually only the floors for the final assembly buildings were laid. The building itself was to be completed just prior to use from pre-fabricated components. The new sites were constructed combining the best techniques of concealment and they were less vulnerable to bombing attack. Deceptive activity was maintained at the old sites.<sup>10</sup> This program was so effective that the Allies did not locate the first of the new sites until April 27, 1944, three months after construction began.<sup>11</sup>

The British did not initially associate the "ski" sites with the V-1 program, but in early December intelligence specialists pieced together the puzzle and ordered bombing attacks on the sites. Twenty-four of the 95 known ski sites were attacked on December 24, 1943, by 672 bombers which dropped 1,472 tons of bombs. While 3,000 tons of bombs were expended on the ski sites during the period December 5 to December 31, 1943, the Allies destroyed only seven of the sites. Attacks on ski sites continued until June 12, 1944. During the last six months of the bombing offensive tons of bombs were dropped to neutralize the ski sites.<sup>12</sup> Unfortunately for the British the ski sites became more of a decoy than an operational necessity to the V-1 program. The revised sites which represented the heart of the forthcoming V-1 bombardment went untouched.

The Allied invasion of France acted as a catalyst in the implementation of the V-1 program. Within six days of the invasion 873 V-1's were distributed to launching teams and great quantities of fuel were delivered. On June 11 a conference was held a few miles from Paris and it was agreed that the long awaited offensive should commence the

---

<sup>10</sup> Ibid., pp. 47-48.

<sup>11</sup> Ibid., p. 162.

<sup>12</sup> Ibid., pp. 45-47

following evening.<sup>13</sup> Unforeseen difficulties inherent in crash programs made it impossible to meet the ordered launch time. Finally at 4:00 A.M. on June 13 the first of a long series of V-1 missiles crossed the English coastline.<sup>14</sup>

#### CHARACTERISTICS

The V-1 was classed as a mid-wing monoplane with a wing span of 17 feet 6 inches. Its overall length was 26 feet. The fuselage was 2 feet 7 inches in diameter. The payload was a warhead which weighed over a ton with an explosive charge of approximately 1,900 pounds. The total launch weight was about 4,000 pounds.<sup>15</sup>

The unique feature of the V-1 was its propulsion system. This was the first jet propelled weapon of the war to be used offensively. Its jet engine was of the simplest type, an impulse duct engine or more commonly called a "pulse jet" engine.

The pulse jet of the type used for the V-1 was extremely simple in construction and functioning. It consisted of a cylindrical duct approximately 11 feet long. The front end of the duct contained a bank of spring loaded air valves, which can be likened to the louver closure on an ordinary kitchen exhaust fan. Forward motion of the missile forced the valve open. Simultaneously fuel was injected into the duct to the rear of the valves. This mixture was ignited causing a higher pressure than that of the incoming air. This in turn caused the air valve

---

<sup>13</sup> Ibid., pp. 69-70.

<sup>14</sup> Ibid., p. 163.

<sup>15</sup> Leonard Bridgman (ed.), Jane's All the World's Aircraft 1945-46 (New York: Macmillan Co., 1946), pp. 147c-148c.

assembly to close forming a "wall" against which the internal pressure was exerted. The other end of the duct was open allowing the expanding exhaust gasses to escape. This condition exerted unequal forces in the engine with a thrust being generated in the direction of forward motion of the missile. When the pressure inside the duct reduced below the pressure being exerted on the front side of the air valves, the valves again opened and the process was repeated. This cycle of operation recurred 40 to 45 times per second. The theoretical forward speed of the V-1 was approximately 400 miles per hour.<sup>16</sup>

Automatic control was accomplished by means of a magnetic compass, gyros and an anemometer. The latter was a small propeller mounted on the nose of the fuselage. The forward motion of the missile caused the propeller to rotate. During flight the revolutions of the propeller were counted and compared with a precalculated number. When the preset number was reached, the missile was forced into a steep terminal dive. The range accuracy thus achieved was not very precise, but when compared to the dimensions of a target like the city of London, extreme accuracy was not required. The typical mean deviation for a 100 mile shot was about six miles.<sup>17</sup>

The magnetic compass worked in conjunction with the gyros to maintain a course to within  $\frac{1}{2}$  degree. As the missile drifted off course the control system would sense the deviation and through electro-pneumatic servo mechanisms the rudder would move to compensate for the error causing the missile to steer back to the predesignated magnetic course. Lateral accuracy thus achieved was about six miles for a 100 mile shot.<sup>18</sup>

---

<sup>16</sup>Ibid.

<sup>17</sup>USFET, op. cit., p. 40.

<sup>18</sup>Ibid.

The major internal power source for the missile was supplied by compressed air. The V-1 carried two spherical containers which were pressurized with air to about 2,000 pounds per square inch.<sup>19</sup> During flight this air was used to drive the gyros, pressurize the fuel tanks and power the servo-mechanisms.

The external shell of the missile was of welded steel construction as was the jet duct. Toward the end of the war some of the weapons incorporated plywood in the wings and fuselage.<sup>20</sup> The wings were fixed and unlike conventional aircraft, the only control surfaces were on the tail assembly.

The V-1 engine required forward motion to develop thrust. Similarly the missile could not be aerodynamically self-controlled until forward motion was achieved. An 180 foot fixed ramp was used to satisfy the initial control requirements. Incorporated into the ramp was a catapult which imparted the initial thrust to the weapon. The ramp used two steel rails to guide the missile in elevation and azimuth. It was oriented in the general direction of the anticipated target and was inclined at approximately six degrees making the exit end over 18 feet high.<sup>21</sup>

While the missile could be preset to make one turn of up to 45 degrees during its flight to the target, this option was not exercised very frequently. The altitude was established prior to launch and until it made its final dive it maintained that preset height. The majority of the V-1's used against England flew between 4,000 and 5,000 feet.

---

<sup>19</sup> Bridgman, loc. cit.

<sup>20</sup> USFET, op. cit., p. 39.

<sup>21</sup> Bridgman, loc. cit.

Against Antwerp the preferred altitude was 3,000 feet or lower.<sup>22</sup>

The maximum range for the early model missiles was about 160 miles. This range could only be achieved under ideal conditions. Cross winds caused constant horizontal correction as did any programmed change in direction; both caused a corresponding decrease in range. During the later V-1 operations the missile weight was reduced by using plywood on certain portions of the airframe and by reducing the size of the warhead. Such missiles could achieve a range of 250 miles. This model was used in March 1945 during the final operations against Great Britain.<sup>23</sup>

A second method of employment was developed to increase the flexibility of the V-1, extend the range, and compound the defensive problem by varying the missile approach direction. The HE 111 medium bomber was used to transport the V-1 to a predetermined launch point where the missile was released to continue to the target in the normal mode.

The speed of the aircraft was sufficient to allow the jet engine to function normally when the missile was released. The forward motion requirement for missile aerodynamic control was likewise satisfied by the forward motion of the aircraft. Considering the range of the mother aircraft the range of the V-1 was increased to about 800 miles.<sup>24</sup>

While versatility was achieved by the inherent mobility of the

---

<sup>22</sup> USFET, loc. cit.

<sup>23</sup> Rowland F. Pocock, German Guided Missiles of the Second World War (New York: ARCO Publishing Co., 1967), p. 103.

<sup>24</sup> M. C. Helpens, The Employment of V-Weapons by the Germans During World War II (Washington: Department of the Army, Office of the Chief of Military History, 1954), p. 37. (USA C&GSC Archives)

mother aircraft certain serious limitations were prevalent. The success of the V-1 was now dependent on the success of the delivery aircraft. Accidents and kills by the British Royal Air Force took a high toll of the available mother aircraft. The accuracy of the V-1 was now a function of aircraft location at the time of release. Since the aircraft operated primarily at night and most launches were over the North Sea, aircraft position had to be determined by instruments. These and other factors seriously degraded the effectiveness and accuracy of this method of operation.

#### BRITISH V-1 EXPERIENCE

Authors writing on the initial V-1 launchings disagree on the volume of the first attack. It appears, however, that of the first 10 attempted launchings only four V-1's reached England, and three of these did not cause any casualties. The fourth impacted on a railway viaduct disrupting rail traffic, killing six people and injuring nine others.<sup>25</sup> No claims were made by the defensive units, but a fuse from a heavy antiaircraft shell was found in the debris of the fourth V-1.<sup>26</sup>

This initial V-1 attack on Britain was the first increment of three distinct attack phases. Phase one lasted from June 13, 1944, until September 5, 1944. Attacks during this period came from Northern France. When the Allies overran the area where most of the launch facilities were located, the Germans were forced to revise their operations until new launch locations could be prepared. The second attack phase began on

---

<sup>25</sup> Collier, op. cit., pp. 74-75.

<sup>26</sup> Pile, op. cit., p. 327.

September 15 when the V-1's were launched from modified Heinkel 111 two-engine bombers. This launching method was used exclusively until January 15, 1945. A subsequent period of inactivity ended on March 3, 1945, when ground launched missiles once again appeared over England.<sup>27</sup> This third phase lasted through March 29, 1945, when the last V-1 to approach Great Britain was destroyed by antiaircraft fire.<sup>28</sup>

During the initial attack period over 6,600 V-1's approached Great Britain at all hours of the night and day. The second period brought about 600 V-1's to the British homeland. In the final phase approximately 120 V-1's threatened Great Britain. London was the target of the vast majority of the V-1's in all three attack phases, but only 2,360 V-1's reached London. Failures resulted from the effects of guidance errors, mechanical malfunctions and defensive efforts.<sup>29</sup>

The strategic damage inflicted by all V-1's landing within the United Kingdom during the period June 13 to September 5, 1944, is summarized in Table 1. The source of this information does not elaborate on the nature of the damage incurred. Accordingly, damage in this case could be superficial or complete destruction of the type facility listed. While this table only covers damage incidence during the first phase of the V-1 offensive it includes the effects of about 97 per cent of the total number of missiles landing within the target area during the entire period from June 13 to March 30, 1945.

---

<sup>27</sup> Mary Catherine Welborn, V-1 and V-2 Attacks Against the United Kingdom During World War II (Washington: Operations Research Office, Johns Hopkins University, 1950). (Mimeographed.), pp. 4-6. (USA C&GSC Archives)

<sup>28</sup> Collier, op. cit., p. 134.

<sup>29</sup> Welborn, op. cit., p. 7.

TABLE I

DAMAGE INCIDENCE BY CATEGORY OF FACILITY<sup>30</sup>  
 PERIOD JUNE 13 TO SEPTEMBER 5, 1944

TYPE FACILITY	NUMBER OF INCIDENTS
Factories.....	179
Hospitals.....	67
Schools.....	36
Railroads (bridges, stations, main lines, yards, etc.).....	141
Utilities (power lines, gas works, telephone exchanges, water mains, bus depot, etc.).....	146
Highways.....	627
Military Establishments (AA gun sites, signal stations, camps, hospitals, billets, etc.).....	57

The toll on the citizenry of London amounted to almost 6,000 killed, 40,000 injured and 75,000 homes destroyed or damaged.<sup>31</sup> In one London suburb three of every four houses in the borough were damaged or destroyed by V-1's. For every weapon dropped on British soil eight or nine people were killed or seriously injured.<sup>32</sup>

The damage caused by the V-1's could have been more severe. The British realized that strategic bombing of the launch sites could not prevent all of the V-1 launchings. Accordingly, even before the first V-1 attack in June 1944, a defense was planned to destroy the missile as it approached the target area.

<sup>30</sup>Ibid., p. 24.

<sup>31</sup>John Kirk and Robert Young, Jr., Great Weapons of World War II (New York: Walker and Co., 1961), p. 331.

<sup>32</sup>Collier, op. cit., p. 125.

## LONDON DEFENSE

The paucity of definitive information relative to the V-1 led the defense planners to consider a broad spectrum of characteristics for the missile. The V-1 defense plan was further complicated by the simultaneous plans for the forthcoming Normandy invasion. The homeland defense was competing for men and materiel resources needed to support the invasion.

Estimates of flight parameters for the V-1 did not rule out a missile similar to existing manned aircraft. Therefore, it was decided that the defensive techniques then employed against conventional aircraft would probably be effective against the new threat. Both interceptor aircraft and antiaircraft artillery would be used in the defense. The plan called for fighters to patrol at 12,000 feet in parallel belts astride the approach axis of the London-bound V-1's. The first belt was about 20 miles off the coast. The second belt was over the coast line, and the third belt was 15 to 20 miles inland. These patrols commenced with the warning of an imminent attack. When the missiles began to arrive additional fighters would patrol the same belts at an altitude of 6,000 feet. Immediately behind the third fighter patrol belt was a belt of antiaircraft guns. Just outside the city limits of London a belt of barrage balloons provided the final defensive measure.<sup>33</sup> Figure 1 is a schematic representation of this defense.

After the inauspicious beginning on June 13, 1944, the V-1 attacks began in earnest on June 15. The London defense was deployed as planned with 192 heavy antiaircraft guns and a like number of light antiaircraft

---

<sup>33</sup> Ibid., p. 57.

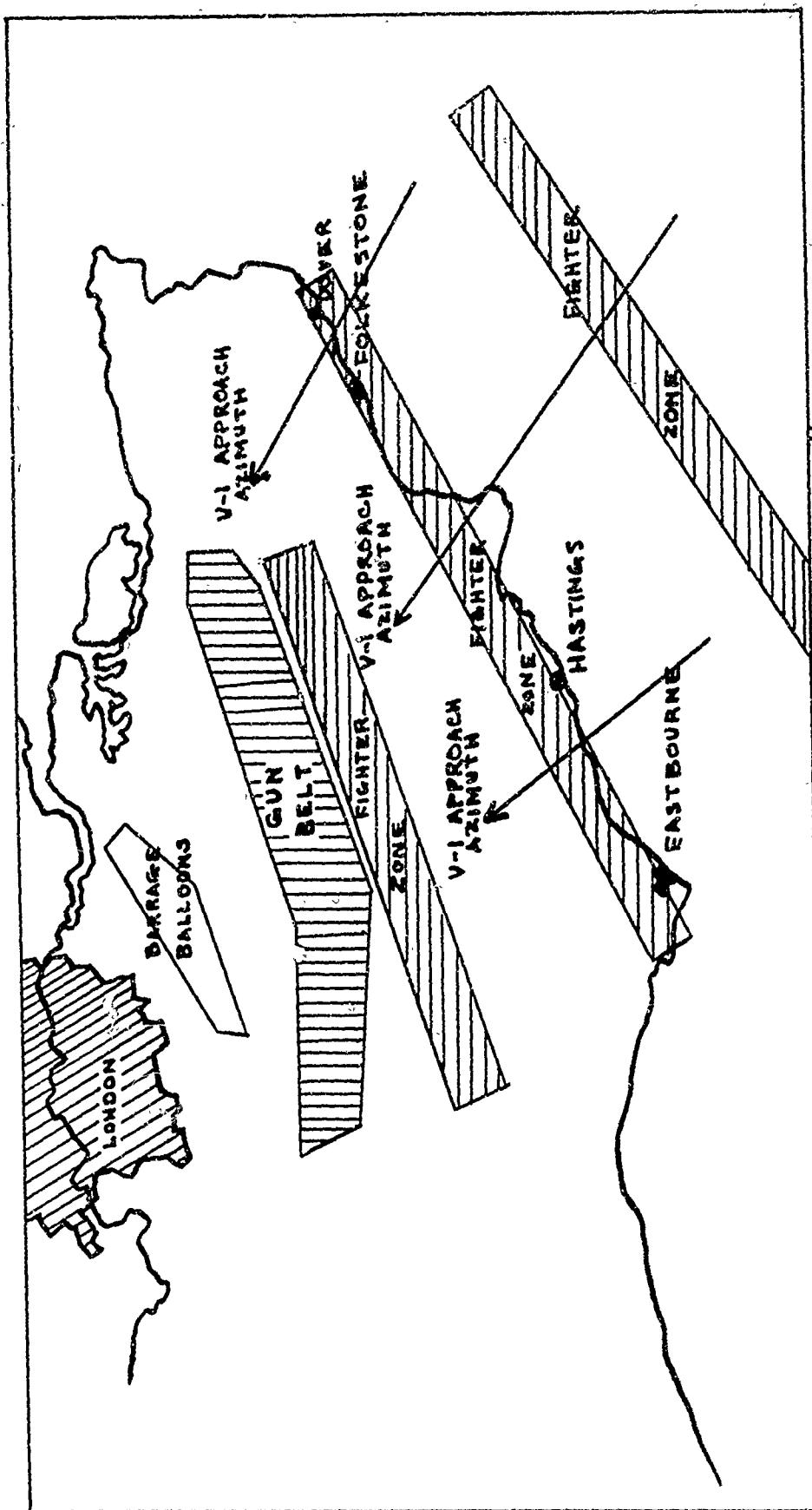


Figure 1. The Initial London Defense Through July 16, 1944<sup>34</sup>

<sup>34</sup> Welborne, op. cit., Fig. 2; Collier, loc. cit.

guns. The defense grew to a total deployment of 376 heavy guns and 576 light guns by the end of June.<sup>35</sup>

The weaknesses of the defense were soon apparent. The high degree of coordination between fighters and antiaircraft artillery necessary to obtain maximum effectiveness from both was never achieved. Restrictions were placed on the guns to prevent fighters in close pursuit of a V-1 from being fired upon.<sup>36</sup>

The proximity of the gun belt to the defended area created another problem. V-1's which were damaged by antiaircraft fire fell in the defended area. The problem was so severe that some guns were prohibited from firing at passing V-1's in the hope that the missile would over-fly the defended area before executing its terminal dive.<sup>37</sup>

Technical difficulties further decreased the defense efficiency. The newly developed proximity fuzes were prohibited from use over populated areas to prevent civilian property damage and casualties. If the fuze failed to detonate the projectile near the V-1, the projectile would continue on a ballistic path finally exploding when it fell to the earth. The fuze incorporated a self-destruct feature to destroy the projectile high in the air after a fixed time of flight, however, this feature proved to be unreliable.<sup>38</sup> Radars were sited in depressions or hollows taking advantage of the natural screening obtained and thereby reducing effects of enemy electronic countermeasures which, incidentally, never developed. The siting techniques used for this purpose were sound for high altitude attacks but proved to be a limiting factor against the V-1 which

---

<sup>35</sup> Pile, op. cit., p. 328.

<sup>36</sup> Collier, op. cit., pp. 86-89.

<sup>37</sup> Pile, loc. cit.

<sup>38</sup> Collier, op. cit., pp. 92-93.

approached at relatively low altitudes.<sup>39</sup>

To achieve greater success with the antiaircraft artillery it was decided to move the guns into a belt along the coast. The belt was 5,000 yards deep and the guns fired 10,000 yards out to sea.<sup>40</sup> This deployment offered solutions to most of the inadequacies of the earlier defense. Many of the V-1's brought down by gun fire fell harmlessly into the water. This also happened with unexploded projectiles. Radars were sited optimally with little interference from ground formations. A change in the engagement rules for aircraft allowed maximum use of the capabilities of the guns.

Areas vacated by the guns were used to expand the terminal barrage balloon defense. Fighters had the entire area between London and the rear of the belt without restriction. The seaward fighter patrol area and the patrol area along the coast remained, but flying was prohibited below 8,000 feet over the gun belt.<sup>41</sup> The new defense which was fully operational by July 17 is shown schematically in Figure 2.

Results of these changes were encouraging. During the previous period, June 13 to July 13, the defense destroyed approximately 40 per cent of all V-1's reported operating over Great Britain. For the period July 13 to September 5 the defense effectiveness increased to 54 per cent. Effects of the defense adjustment on antiaircraft artillery were dramatic; the success percentage tripled. However, defense adjustment decreased fighter success from 30 per cent to 23 per cent.<sup>42</sup> These percentages are based on the total number of V-1's operating and

<sup>39</sup> Pile, op. cit., p. 330.

<sup>40</sup> Ibid., p. 334.

<sup>41</sup> Ibid.

<sup>42</sup> Welborn, op. cit., p. 7.

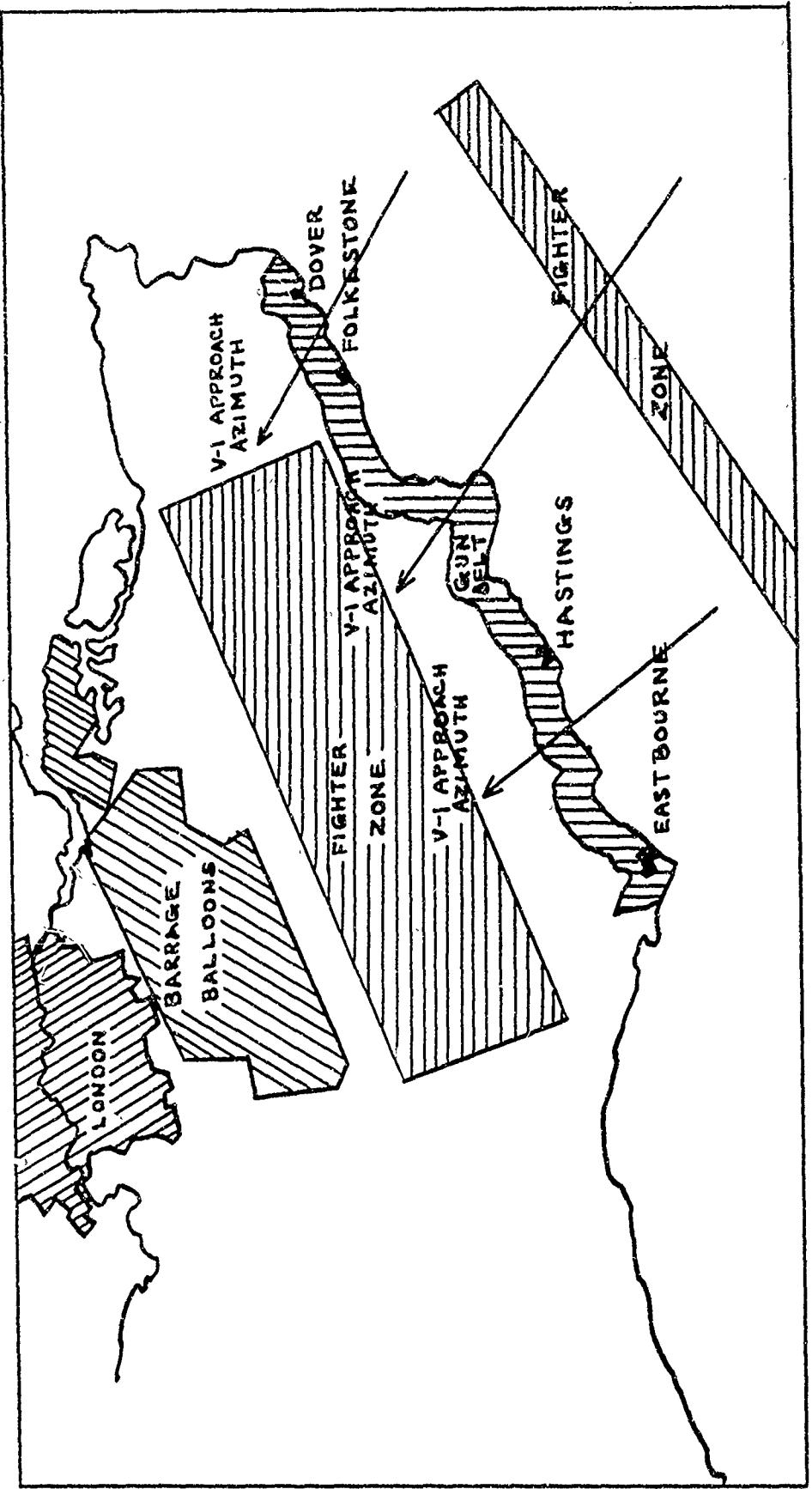


Figure 2. The Revised London Defense After July 16, 1944.<sup>43</sup>

<sup>43</sup> Welborne, op. cit., Fig. 2; and Pile, op. cit., p. 334.

number of V-1's that could be launched; V-1's launched could not exceed the number of bomber sorties committed to this task. With the degeneration of the Luftwaffe prior to and during this period a significant reduction in the number of V-1's approaching the defense was inevitable when compared to the previous ground-launched phase. The total number of missiles operating during this time amounted to 1/10 of what it had been during the initial phase.

With constant reductions of men and materiel for defense during phase two and the increased requirements associated with the additional directions of attack, it is remarkable that the defenses increased their effectiveness. Total attrition reached 65 per cent during this time; fighter attrition was approximately 10 per cent and the guns achieved nearly 55 per cent.<sup>44</sup>

The final phase of the V-1 attacks was anticlimactic for the defenders. It was characterized by attacks from ground launch positions in Western Holland. The air-launched attacks had ceased and the total defensive effort could now be devoted to this new threat. The basic concepts devised in phase one were still valid. Fighters patrolled the North Sea. The next line of defense was a gun belt backed up by additional fighters operating between the belt and London.<sup>45</sup>

The total effort of the Germans amounted to 124 V-1's that approached the target area of which nearly 75 per cent were destroyed by the defenses. During this final phase the guns reached their peak of efficiency; they destroyed over 70 per cent of the missiles operating in the target area. Only 13 of the V-1's launched reached

---

<sup>44</sup> Welborne, op. cit., p. 7. <sup>45</sup> Collier, op. cit., p. 134.

their objective. This represented about 10 per cent of those missiles that theoretically could have reached the target if it hadn't been for malfunctions and the defenses. The defenses improved greatly from the early days in June, July and August 1944 when over 40 per cent of the V-1's reached the target.<sup>46</sup> These results are impressive particularly when the characteristics of the V-1 are considered. The V-1 was judged to be eight times more difficult to destroy than a conventional aircraft flying a similar course.<sup>47</sup> The characteristics of the missile provide some explanation for its relative invulnerability.

The lessons learned by the British in the summer and early fall of 1944 would serve the Allies well in the coming months. Shortly after the British captured the port city of Antwerp it became apparent to the Allies that the Germans would attempt to interfere with port operations by attacking it with V-1 missiles. The situation demanded an immediate highly effective defense. The experience gained in the defense of London provided the basis for the defense of Antwerp.

---

<sup>46</sup> Welborn, loc. cit.

<sup>47</sup> USFET, op. cit., p. 39f.

## CHAPTER II

### THE DEFENDED AREA

The planners of the 1944 Allied invasion of Normandy recognized the need for port facilities to support subsequent operations. Their plans, however, did not materialize on schedule. Operations progressed at an unanticipated rate. The logistics situation deteriorated threatening to halt further progress when the British 21 Army Group unexpectedly captured the major port of Antwerp virtually intact.

#### SIGNIFICANCE OF ANTWERP

When the directive for operation OVERLORD, the Allied invasion of the European continent, was issued to General Eisenhower on February 12, 1944, the necessity of adequate port facilities was clearly delineated. In part the directive read:

You will enter the continent of Europe and, in conjunction with the other United Nations, undertake operations aimed at the heart of Germany and the destruction of her armed forces. The date for entering the Continent is the month of May, 1944. After adequate Channel ports have been secured, exploitation will be directed towards securing an area that will facilitate both ground and air operations against the enemy.<sup>1</sup>

From the beginning plans for OVERLORD recognized the military necessity for adequate ports. The general strategy for the operation

---

<sup>1</sup>Dwight D. Eisenhower, Report by the Supreme Commander to the Combined Chiefs of Staff on the Operations in Europe of the Allied Expeditionary Force 6 June 1944 to 8 May 1945 (Washington: U. S. Government Printing Office, nd.), p. vi. (The title of this source is hereafter referred to as Report.)

focused on the first sentence of the foregoing quote, "...undertake operations aimed at the heart of Germany and the destruction of her armed forces." The heart of Germany was the Ruhr. To get there meant crossing the Rhine River. An avenue north of the Ruhr was considered the most important route for forces attacking the Germany heartland.<sup>2</sup>

In General Eisenhower's words:

...the northern channel of operations was the perfect location, from a logistic viewpoint, of Antwerp, the finest port in northwest Europe. Seizure and use of that port would vastly shorten our lines of communication, and it was clear that when we once arrived on the borders of Germany logistic problems were going to be critical.<sup>3</sup>

As events unfolded the importance of Antwerp increased. The objective of the initial phase of OVERLORD was to establish a lodgement on the continent containing sufficient port facilities to maintain 26 to 30 divisions and allow follow up shipments of up to five divisions per month.<sup>4</sup> This was to be accomplished by the early capture of Cherbourg and other Brittany ports.

Even with the capture of Cherbourg and the "lesser" ports in the initial beachhead area the subsequent build up phase could not be supported without additional facilities. The potential of Cherbourg and the land lines of communication leading from it could not support the volume of troops and equipment planned for the operation.

To solve the problem it was decided to construct artificial ports. The planners reasoned that some of the world's ports were really artificial utilizing manmade breakwaters. Conventional

---

<sup>2</sup>Dwight D. Eisenhower, Crusade in Europe (Garden City, N. Y.: Doubleday and Company, Inc., 1948), p. 225.

<sup>3</sup>Ibid., pp. 225-226.

<sup>4</sup>Eisenhower, Report.

breakwaters, however, took years to build. The operation being planned had to provide facilities within a few months after the invasion took place. Two requirements had to be met; breakwaters were necessary to provide sheltered water during adverse weather, and piers were necessary to handle cargo vessels that could not be beached for unloading.<sup>5</sup>

The breakwater requirement was to be satisfied by sinking obsolete ships end-to-end forming a barrier. Additionally, prefabricated concrete box-like structures would be towed across the English Channel and sunk in a line forming additional barriers. Piers similar to present day float bridges would be constructed to extend out into the harbor where deep draft ships could be anchored for unloading.<sup>6</sup>

Two artificial harbors were planned, one in the American sector and one in the British zone. Before construction could be completed a severe storm lashed the Normandy coast and the American harbor was destroyed.<sup>7</sup> After repairs the British harbor was completed and operated until November 19, 1944.<sup>8</sup>

The loss of the artificial harbor in the American sector eliminated the second most important single port facility in the original OVERLORD plan. Only Cherbourg was planned to handle greater tonnages than the now ruined harbor.<sup>9</sup>

---

<sup>5</sup>Roland G. Ruppenthal, Logistical Support of the Armies, "U. S. Army in World War II" (2 vols., Washington: U. S. Government Printing Office, 1953-1959), I, pp. 271-272. (Hereafter this title is cited as Logistical Support.)

<sup>6</sup>Ibid., pp. 275-278.

<sup>7</sup>Ibid., pp. 406-413.

<sup>8</sup>Ruppenthal, Logistical Support, II, op. cit., p. 60.

<sup>9</sup>Ruppenthal, Logistical Support, I, op. cit., pp. 296-297.

Although the original plan called for Cherbourg to be taken by D+8, June 14, it was not in Allied hands until June 26.<sup>10</sup> Anticipated destruction had been accomplished by the retreating Germans. Damage was so extensive that port operations did not begin until July 16.<sup>11</sup> The original plan called for port rehabilitation to be accomplished in three days with operations beginning shortly thereafter. However, the last major area of the port was not opened until October 8 and all planned facilities in that area were not completed until December 15.<sup>12</sup>

The impact of these delays is seen in the cargo handling statistics. Cherbourg was to be operational, though at a reduced capacity, by the end of June. Planners estimated that 34,000 tons would be discharged by the end of June. But at the end of June the port lay in ruins. By July 25 it was expected that the capacity would have reached 150,000 tons, but by this date only 18,000 tons had been handled.<sup>13</sup>

There were also delays in the initial operations on the continent. To maintain momentum combat troops were landed ahead of schedule. Arrival of service units was then delayed. Additional combat forces had to be maintained with fewer service units. Slow forward progress created a storage space shortage for the huge quantities of supplies needed for future operations. Maneuver room for combat elements was limited and overall security was threatened by the shallow depth of the beachhead.

---

<sup>10</sup>Eisenhower, Report, op. cit., pp. 6, 32.

<sup>11</sup>Ruppenthal, Logistical Support, II, op. cit., p. 72.

<sup>12</sup>Ibid., p. 78.

<sup>13</sup>Ruppenthal, Logistical Support, I, op. cit., p. 464.

It was essential that the lodgement area be expanded; however, if the expansion covered too large an area or proceeded too rapidly, service unit capability could be overextended.<sup>14</sup>

When the breakout from the lodgement finally occurred, the problem of overextension was aggravated. Armor spearheads outdistanced their logistical support and aircraft had to be diverted from other commitments to airlift supplies to forward supply points.<sup>15</sup> Diverting aircraft from previous commitments was not a long-term solution to the growing supply dilemma.

Performance of the British 21 Army Group was typical of the rapidly advancing forces all along the front during late August and early September. On August 25 elements of the Second British Army crossed the Seine River. The Second Canadian Corps made crossings the following day. Elements of 21 Army Group captured Antwerp on September 4. At this time the British forward units were approximately 400 miles from their source of supplies in Normandy.<sup>16</sup>

The British advance covered 195 miles in one four-day period. The Germans were unable to stop the advance; nor were they able to prepare Antwerp for destruction. Consequently the Germans hastily vacated the city leaving it intact.<sup>17</sup> Mounting Allied supply problems

---

<sup>14</sup> Martin Blumenson, Breakout and Pursuit, "U. S. Army in World War II (Washington: U. S. Government Printing Office, 1969), pp. 4-5.

<sup>15</sup> Eisenhower, Report, op. cit., pp. 48-49.

<sup>16</sup> Field Marshal The Viscount Montgomery of Alamein, "Operations in North-West Europe From 6th June, 1944, to 5th May, 1945," The London Gazette, September 3, 1946, Supplement, pp. 4442-4443. (Hereafter referred to as The London Gazette, Supplement.)

<sup>17</sup> Eisenhower, Crusade in Europe, op. cit., pp. 303-304.

were suddenly reduced. As soon as the port could be brought into operation port capacity would no longer be a constant determinant in the course of the tactical battle.

#### DESCRIPTION

Antwerp is located on the Schelde River about 50 miles from the North Sea. It is connected to the interior of Belgium by a system of roads, railroads and canals. Antwerp is one of the world's great ports ranking with Rotterdam, Hamburg, and New York. The potential of Antwerp dwarfed the capacity of the other facilities available to the Allies. Logistics planners based their initial calculations on an import of 40,000 tons per day limited only by clearance capabilities.<sup>18</sup> This figure can be compared with 28,000 tons for Cherbourg after extensive alteration and new construction.<sup>19</sup>

The Schelde River was over 500 yards wide at Antwerp; this permitted easy maneuvering of the largest ships. The port offered over 29 miles of quays, all of which were useable even at low tide. Harbor equipment included 600 hydraulic and electric cranes, numerous floating cranes, loading bridges, and floating grain elevators.<sup>20</sup>

Antwerp's storage facilities included 900 warehouses, a million-bushel capacity granary, and 750,000 cubic feet of cold storage. Petroleum storage totaled 124,000,000 gallons in 498 storage tanks. These could be filled directly from tanker berths.<sup>21</sup>

---

<sup>18</sup> Ruppenthal, Logistical Support, II, op. cit., p. 111.

<sup>19</sup> Ibid., p. 77.

<sup>20</sup> Ibid., p. 104.

<sup>21</sup> Ibid.

Over 500 miles of railway blanketed the Antwerp area. This network was tied to the Belgian transportation network consisting of 3,250 miles of railways and 1,370 miles of navigable waterways. Additionally a large quantity of railroad rolling stock was immediately available in the port area.<sup>22</sup>

Here was a port more than 300 miles closer than Cherbourg to the forward elements of U. S. forces in the north. Motor transport requirements then existing could be greatly reduced. Operations through the port of Cherbourg could only support 21 divisions, six of which had to be supplied by motor transport. Through Antwerp 54 divisions could be supported by rail. In other words the effort required to support a division from Cherbourg was almost three times as great as the effort required to supply that same division from Antwerp.<sup>23</sup>

Destruction by the Germans of other ports captured to this time was suddenly negated. Antwerp could handle more cargo in one day than both the artificial port on the beaches of Normandy and Cherbourg combined. The destruction of the American artificial harbor in June became insignificant. The unanticipated delay in opening Cherbourg and the associated logistic complications would soon be overcome.

German opposition was not ended, however, and it was two months before the first ship could enter Antwerp. The Germans realized the significance of Antwerp to the Allied operations and turned to a defense of the river approach to the city and aerial bombardment to deny the usefulness of this important logistics keystone.

---

<sup>22</sup>Ibid., p. 104-105.

<sup>23</sup>Ibid., p. 49.

## GERMAN REACTION

German forces continued to hold the north bank of the Schelde River after the Allies captured Antwerp. At the mouth of the Schelde River there is a large island which was also occupied by the Germans.

Before the port of Antwerp could be used the approaches had to be cleared. This task conflicted with the overall mission of undertaking "operations aimed at the heart of Germany" as delineated in the directive for OVERLORD. However, operations aimed at the heart of Germany could not be conducted without the additional logistical support promised by the early opening of Antwerp. In the words of General Bradley written on September 21, 1944, "...all plans for future operations always led back to the fact that in order to supply an operation of any size beyond the Rhine, the port of Antwerp is essential."<sup>24</sup>

Accordingly the Supreme Commander directed the British to establish bridgeheads over the Rhine but not to go beyond that point until Antwerp or Rotterdam could be opened.<sup>25</sup> This decision resulted in "Operation Market-Garden" designed to secure the bridgeheads and flank the Siegfried Line on the north before the retreating Germans could consolidate their defense. Since sufficient forces were not available to conduct both operations simultaneously, clearance of the approaches to Antwerp could not begin before late October.<sup>26</sup>

---

<sup>24</sup> Eisenhower, Crusade in Europe, op. cit., p. 321, based on personal correspondence between General Omar Bradley and General Eisenhower dated September 21, 1944.

<sup>25</sup> Montgomery, The London Gazette, Supplement, op. cit., p. 4443.

<sup>26</sup> Eisenhower, Crusade in Europe, op. cit., pp. 326-327.

The task of clearing the north bank of the Schelde fell to the Canadian Army. A joint effort by the Canadians and an amphibious operation by the British reduced the German defenses in South Beveland, a narrow peninsula extending from Antwerp westward toward Walcheren Island. The fighting was particularly difficult as the terrain required fighting in waist-deep water.<sup>27</sup>

After securing South Beveland an amphibious assault was made on Walcheren Island. Three simultaneous landings were made: one on the east coast, one on the south coast and one on the west coast. Naval bombardment was made difficult by the shallow water surrounding the island. Also the landings were heavily opposed. The air forces contributed by blasting the dikes and submerging large portions of the island. Enemy resistance ceased on November 9 under the pressure of the three-pronged assaults.<sup>28</sup>

Land approaches to Antwerp were now cleared. The last task prior to opening the port was to clear the Schelde River. The Germans had heavily mined the river with their usual thoroughness. The Navy finished the mine sweeping operations on November 26. On November 28, 1944, the first ship docked.<sup>29</sup>

However, the Germans were not entirely subdued. At about the same time that the Canadians began operations to clear the land approaches west of Antwerp the Germans commenced attacking the port area with the V-1 and V-2 weapons.<sup>30</sup>

---

<sup>27</sup>Eisenhower, Report, op. cit., pp. 68-69.

<sup>28</sup>Ibid.

<sup>29</sup>Ruppenthal, Logistical Support, op. cit., p. 110.

<sup>30</sup>Eisenhower, Crusade in Europe, op. cit., p. 328.

V-1 attacks against Antwerp continued until March 30, 1945. Four thousand eight hundred V-1's were flown against the city. Of these over 2,700 presented a threat to the port complex. Less than 10 per cent landed in the defended area.<sup>31</sup> These results will be examined in detail in subsequent chapters.

The Luftwaffe never seriously threatened the port of Antwerp after the Allied occupation in September 1944. German aircraft activities over the Antwerp defenses were sporadic and inconsequential.

The Ardennes counterattack, considered by many a last major German offensive in World War II, was oriented on Antwerp. The apparent overall objectives of the Ardennes offensive were to split the Allied armies apart and then to defeat the 21 Army Group before the Americans could react.<sup>32</sup> Speculation of the consequences of German success is unlimited. The significance of the Ardennes offensive to the antiaircraft artillery defense of Antwerp will be brought out in later discussion.

With the capture of Antwerp the Allies acquired a logistics key to "...operations aimed at the heart of Germany...." After the fall of Antwerp difficulties encountered during the initial operation on the continent seemed less significant to future plans. Once German ground operations ceased threatening port operation, attention was

---

<sup>31</sup> Headquarters IX Air Defense Command, Historical and Statistical Summary, 1 January 1944-1 June 1945, p. 32. (Hereafter referred to as IX ADC Summary.) (USACGSC Archives)

<sup>32</sup> Hugh M. Cole, The Ardennes: Battle of the Bulge, "U. S. Army in World War II" (Washington: US Government Printing Office, 1965), p. 17.

focused on the defense of this vital facility against the V-1 missile. The following chapter describes the Antwerp defense from its conception until the end of its usefulness.

## CHAPTER III

### THE DEFENSE

Early in October 1944 Allied intelligence discovered German movements and preparations indicating that a V-1 attack was to be directed at the cities of Brussels and Antwerp. Both cities were located in the British zone of responsibility thereby putting the task for their defense on the 21 Army Group. By this time the V-1 was well known from experience in England. Thus taking advantage of recent experiences in Great Britain and recognizing the successes achieved by antiaircraft, antiaircraft units were employed as the primary defense of Antwerp.<sup>1</sup> As the 21 Army Group had limited available resources it immediately requested assignment of U. S. antiaircraft units to assist in the defense. British plans called for the U. S. units to assume responsibility for Antwerp while British forces defended Brussels.<sup>2</sup>

#### DEFENSE PHASES AND UNIT DEPLOYMENTS

Advanced elements of the 30th AAA Group arrived in Antwerp on October 22, 1944. Three gun battalions assigned to the Group at that time closed in the Antwerp area by October 25. The U. S. units

---

<sup>1</sup>United States Army Air Defense School, Air Defense, An Historical Analysis (Ft. Bliss, Texas: U. S. Army Air Defense School, June 1965), II, p. 147.

<sup>2</sup>Headquarters Antwerp X, Report No. 1, 14 December 1944, pp. 1-2. (Hereafter referred to as Antwerp X, Rpt. 1.) (USACGSC Archives)

joined two regiments of the British 80 AA Brigade that were already providing defense. A British searchlight regiment minus two batteries was also present.<sup>3</sup>

"Antwerp X" was the official designation of the command given the mission to prevent the fall of V-1's within the specified vital area.<sup>4</sup> To accomplish the mission the 21 Army Group planners established a requirement of twelve gun battalions and six automatic weapons battalions.<sup>5</sup>

During the initial period of defense from October 24 until November 22, 1944, the vital area or defended area was carefully defined as that area inside a line connecting a series of map coordinates. At the end of this first phase the area was redefined as that within a circle with a radius measuring 7,000 yards which was centered over the dock area.<sup>6</sup> These areas are diagramed on Figure 3.

An analysis of the defense is best examined in phases correlated with major changes in the directions of attack used by the Germans. Phase I is associated with attacks which originated from the southeast. Phase II concerns the period when attacks approached from the northeast. Additional attacks against Antwerp came from the north. This period is Phase III of the operation.

---

<sup>3</sup>Ibid., p. 5.

<sup>4</sup>Headquarters Antwerp X, Report No. 2 A, 6 December 1944, pp. 2-3. (Hereafter referred to as Antwerp X, Rpt. 2 A.) (USACGSC Archives)

<sup>5</sup>Antwerp X, Rpt. 1, op. cit., p. 3.

<sup>6</sup>Antwerp X, Rpt. 2 A, op. cit., p. 3.

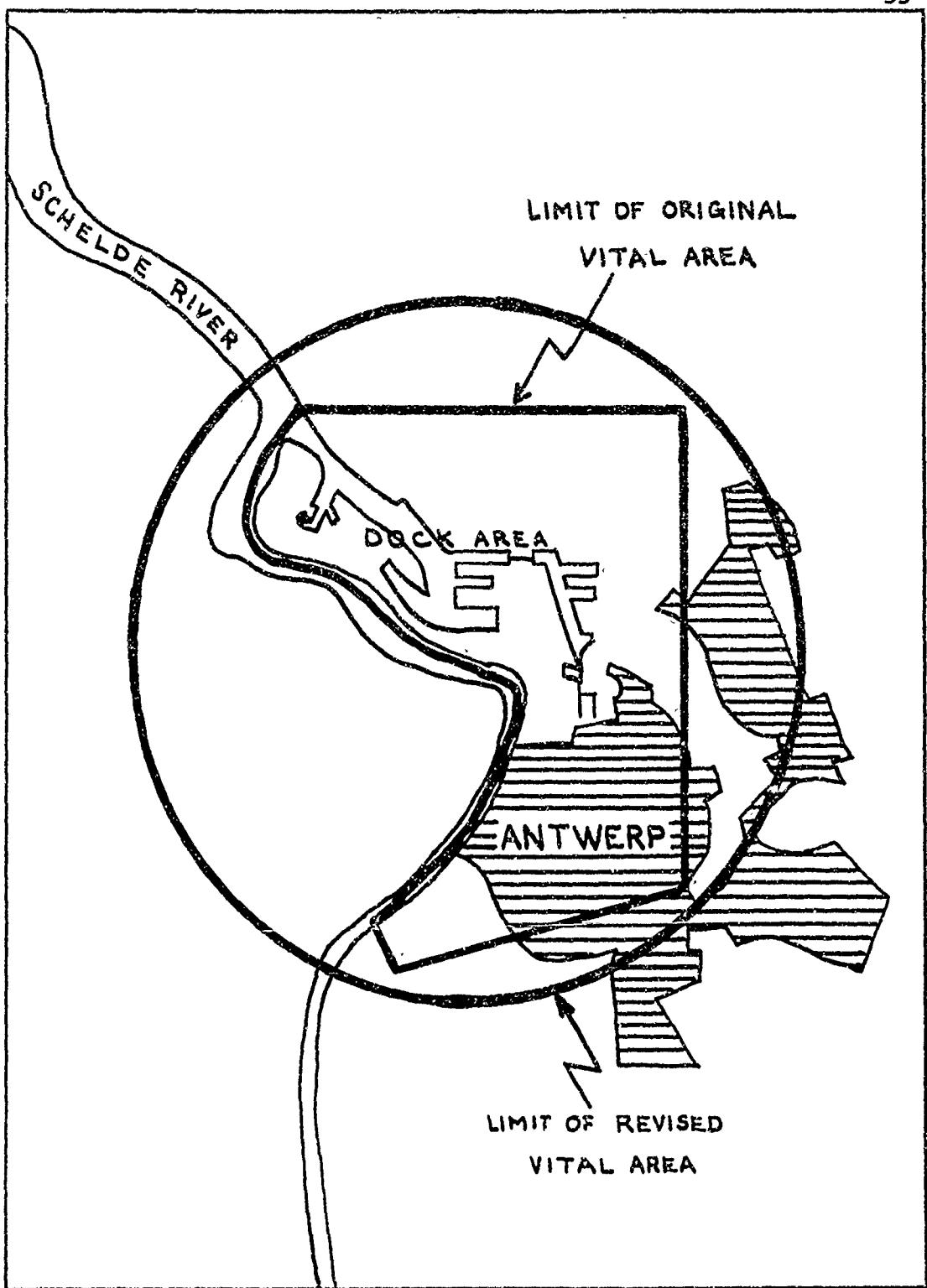


Figure 3. Limits of the Vital Area<sup>7</sup>

<sup>7</sup>Ibid.

Phase I began on October 24, 1944, when the first V-1 was launched against Antwerp.<sup>8</sup> The expected approach azimuth was 90 degrees and units were deployed accordingly. As the situation developed the mean azimuth of the early attacks was found to be approximately 130 degrees.<sup>9</sup> Then the mean azimuth changed slowly toward the north and on December 15, 1944, it was 115 degrees.<sup>10</sup> The launch areas for these attacks are depicted on Figure 4.

U. S. units were assigned to the command and on December 15 a total of 12 gun battalions and 3 automatic weapons battalions were operational in the defense. A British searchlight unit was assigned and remained throughout the various defensive phases. The deployment of these units is shown in Figure 5.

Phase II lasted from December 15, 1944, until January 27, 1945.<sup>11</sup> Activity increased from the northeast and decreased from the southeast during this time. Units were reassigned as this trend developed. Complications resulted from the demands for units to counter the Ardennes offensive, and British units were deployed in the defense to compensate for the loss of U. S. units redeployed to bolster front line antitank defenses. Deployments effective January 27, 1945, are shown in Figure 6. The origin of the northeast attacks is seen in Figure 4.

---

<sup>8</sup>United States Army Air Defense School, loc. cit.

<sup>9</sup>Antwerp X, Rpt. 1, op. cit., Part Two, pp. 1-2.

<sup>10</sup>Headquarters Antwerp X, Report No. 2 B, 14 December 1944, p. 1. (Hereafter referred to as Antwerp X, Rpt. 2 B.) (USACGSC Archives)

<sup>11</sup>Headquarters Antwerp X, Report No. 2 C, 22 December 1944, p. 1. (Hereafter referred to as Antwerp X, Rpt. 2 C.) (USACGSC Archives)

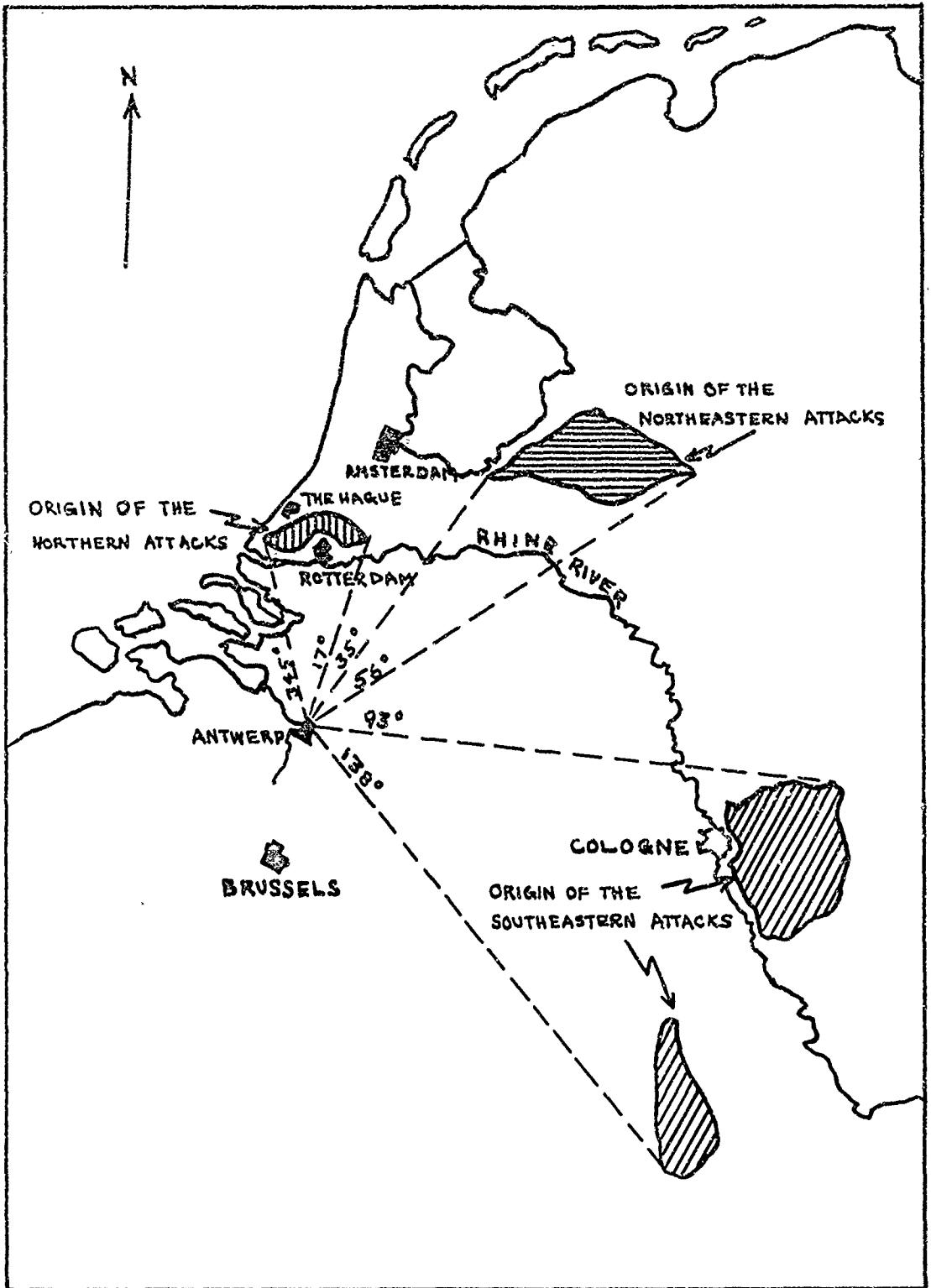


Figure 4. Origin of V-1 Attacks<sup>12</sup>

<sup>12</sup>Helfers, op. cit., Map 2, pp. 40-43.

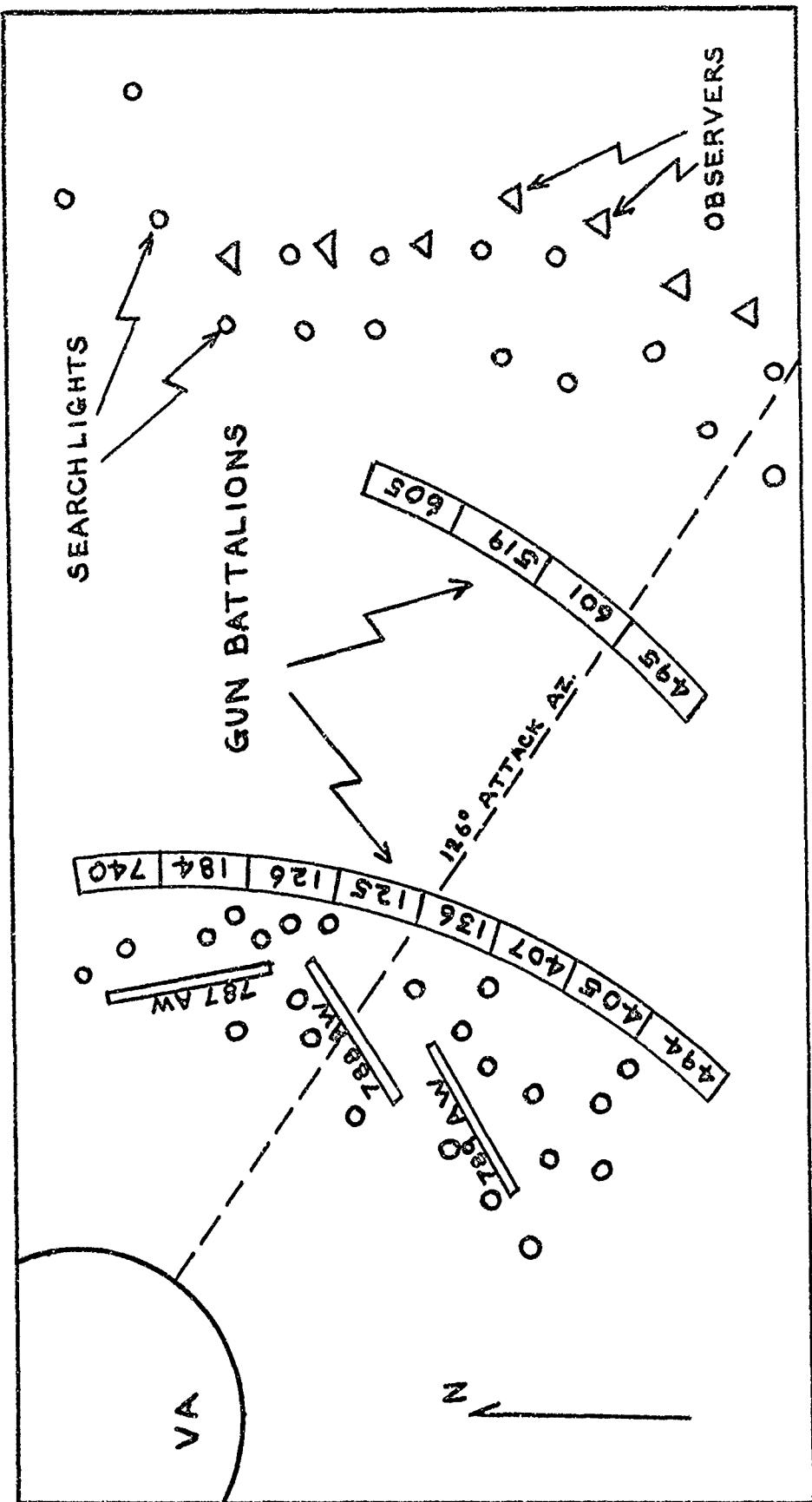


Figure 5. Deployment of Units on December 15, 1944<sup>13</sup>

<sup>13</sup> Antwerp X, Rpt. 1, op. cit., Annex B; and Antwerp X, Rpt. 2B, op. cit., pp. 1-2.

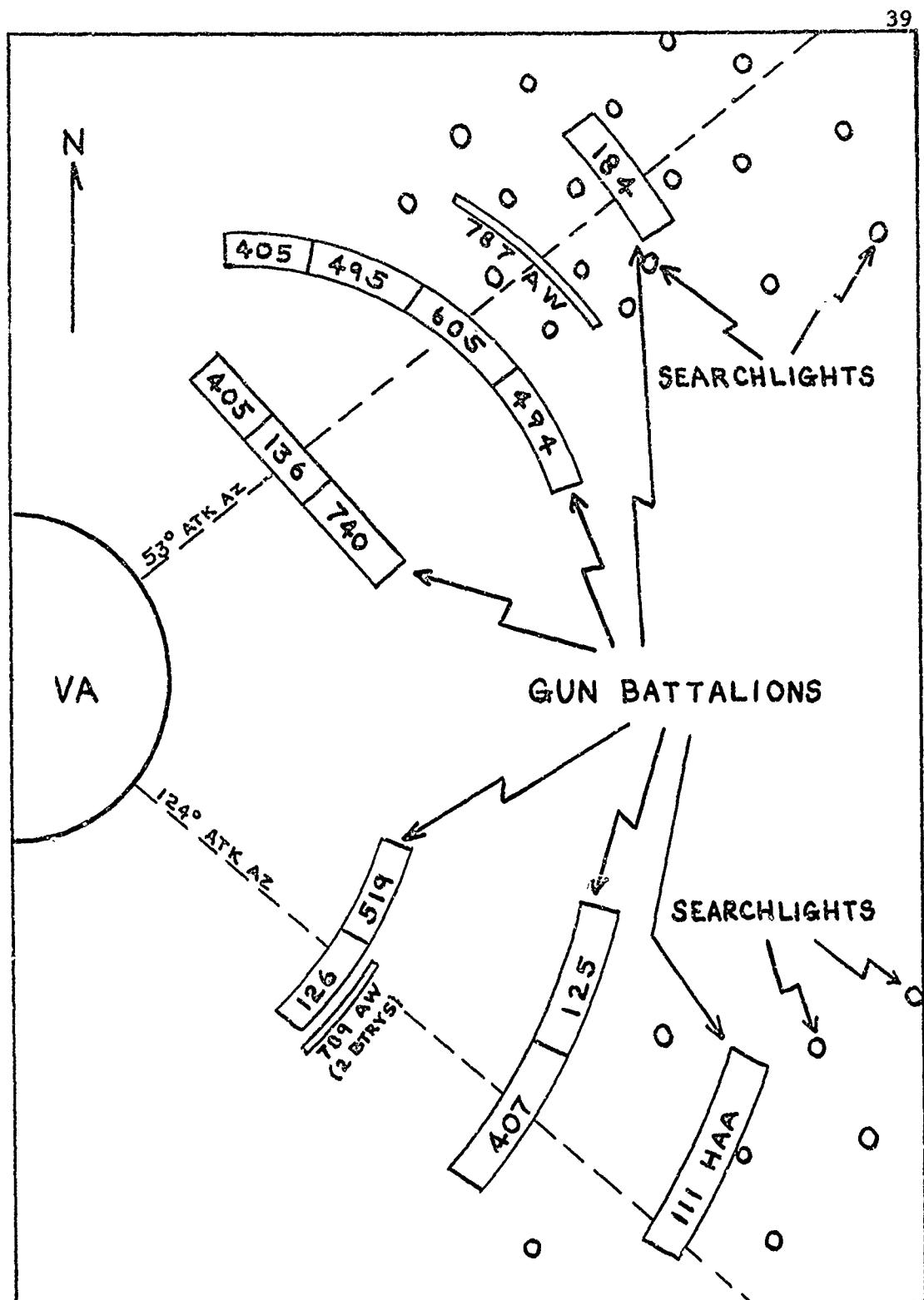


Figure 6. Deployment of Units on January 27, 1945<sup>14</sup>

<sup>14</sup> Headquarters Antwerp X, Report No. 2G, 1 February 1945, Annex A.

Phase III began on January 28, 1945, and lasted until March 30, 1945, when the last V-1 was detected approaching Antwerp.<sup>15</sup> This period was characterized by additional attacks from the north. The range from the launch sites to the defended area was relatively short as shown in Figure 4. This resulted in decreased reaction time for the defense and improved accuracy of the V-1's. The short range of these attacks permitted the V-1's to fly at lower altitudes. Soon more units were made available for assignment to Antwerp X. The deployment on the last day of active defense is depicted in Figure 7.

Throughout these phases command, control and communication were in a constant state of flux. Complete integration of U. S. and British units was essential to accomplish the mission. While the defense was accomplished with antiaircraft units, Air Force elements contributed by providing early warning information.

#### ORGANIZATIONS

The smallest tactical units in the U. S. organizational structure were batteries of four towed 90mm guns as their primary armament.<sup>16</sup> The guns were powered by portable generator sets which also powered the fire control equipment. Fire control equipment included a gun-laying radar (SCR-584) which determined present target position data. The radar was electrically connected to a director (M-9) which is an

---

<sup>15</sup> Headquarters IX Air Defense Command, Historical and Statistical Summary, 1 January 1944-1 June 1945, p. 32. (Hereafter referred to as IX ADC, Summary.) (USACGSC Archives)

<sup>16</sup> Lt. Col. Alvin M. Cibula, Antiaircraft Command and Center Study No. 26, Historical Section Army Ground Forces, 1946, p. 77. (USACGSC Archives)

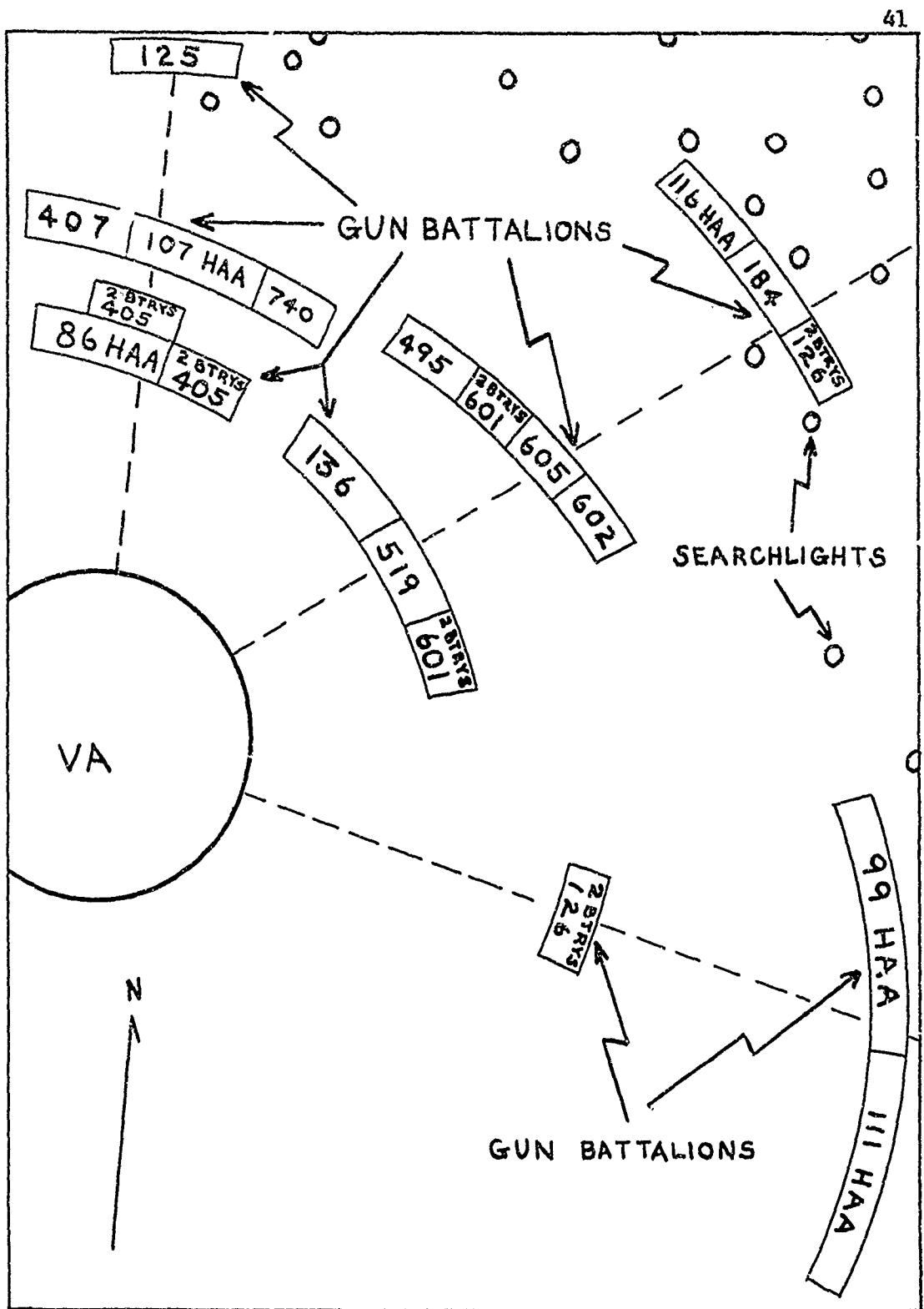


Figure 7. Deployment of Units on March 30, 1945<sup>17</sup>

---

<sup>17</sup> Headquarters Antwerp X, Report No. 21, 3 April 1945, Annex A.

electrical computer used to determine lead angle, quadrant elevation and fuze setting from the present position data.<sup>18</sup> Lead angle is the compensation in the horizontal plane for the expected change in target location during the time the projectile is traveling to the target. Quadrant elevation is the angular aiming adjustment necessary to account for target altitude and to correct for the effects of gravity on a projectile. Figure 8 depicts lead angle and quadrant elevation relative to target present position. Fuze setting is the time setting placed on a projectile fuze. When the projectile is fired and has traveled for the preset time the fuze will detonate the projectile. In case of failure of the radar a stereoscopic height finder was included in each battery. It could provide target altitude or range which could be provided to the director for conversion into firing data. Information from the director was sent electrically to the guns.<sup>19</sup>

The next higher organization was the battalion which consisted of four gun batteries. Two types of gun battalions, mobile and semi-mobile, were employed in the Antwerp defense.<sup>20</sup> The mobile battalions were authorized more personnel and equipment than the semi-mobile battalions to provide for a higher degree of mobility. This was the only distinguishing feature between the two kinds of battalions.<sup>21</sup> One radar set identical to the firing battery radars was provided for each

---

<sup>18</sup> War Department, FM 4-121: Fire Control, Guns (Washington: U. S. Government Printing Office, 1943), pp. 2-14. (Hereafter referred to as FM 4-121.)

<sup>19</sup> Ibid.

<sup>20</sup> Antwerp X, Rpt. 2 A, op. cit., p. 2.

<sup>21</sup> Cibula, loc. cit.

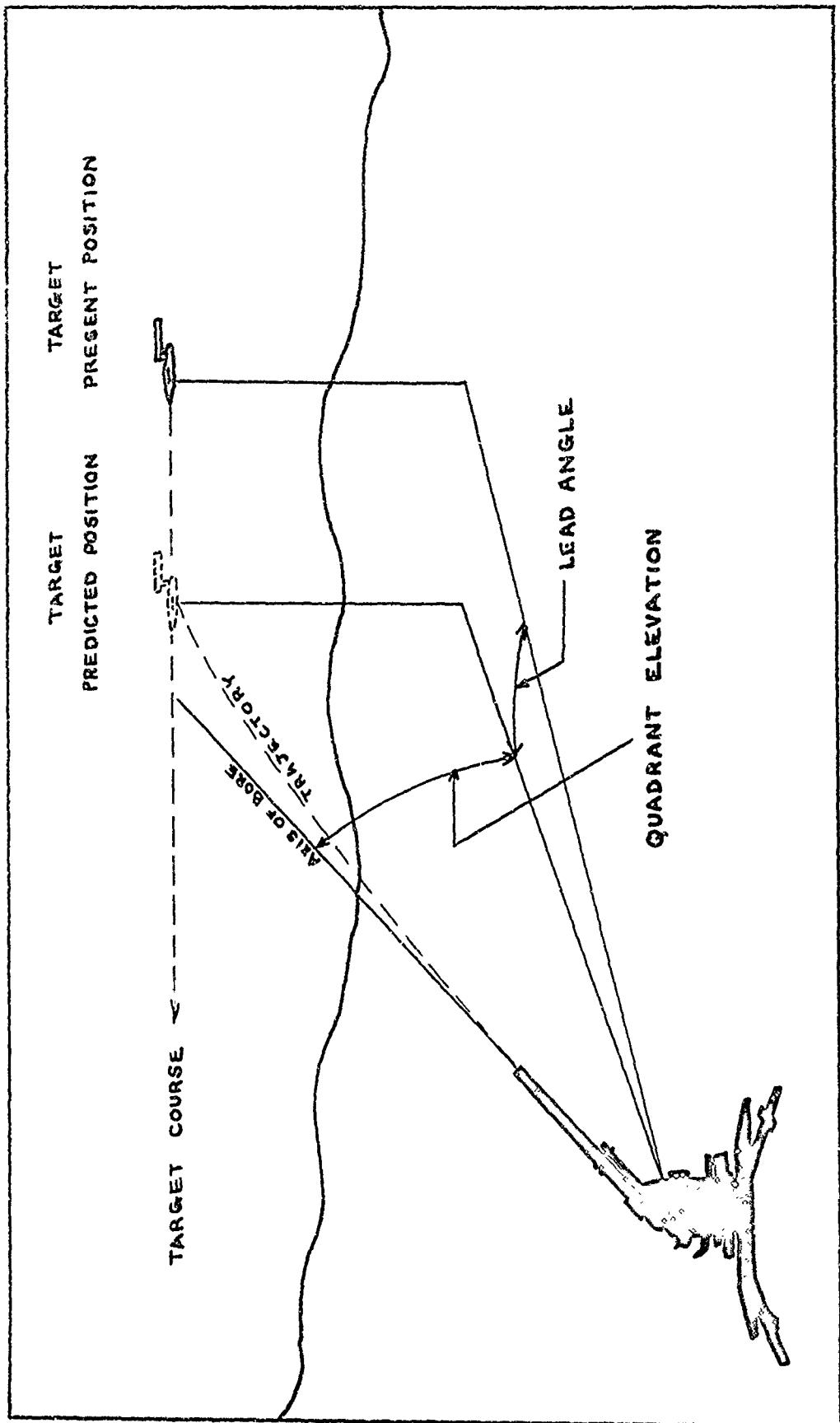


Figure 8. Lead Angle and Quadrant Elevation

battalion.<sup>22</sup> This radar proved invaluable in meeting the operational demands of the Antwerp defense.<sup>23</sup> The use of the battalion radar will be discussed in the succeeding chapter.

The other U. S. firing units employed in the Antwerp defense were automatic weapons (AW) units. These units were also of the mobile and semi-mobile types. The primary armament for these units was eight 40mm guns and eight .50 caliber machine guns.<sup>24</sup> Each 40mm gun had an associated director similar to the director for the 90mm guns. The director was connected electrically to the gun. As the operator at the director tracked the target optically the gun was automatically positioned in azimuth and elevation for firing. Each gun had integral sighting devices to allow direct fire if the director became inoperative.<sup>25</sup> Each battery had one spare director.<sup>26</sup> The .50 caliber machine guns were aimed optically by the gunner with on-carriage sights.

<sup>22</sup> War Department, T/O & E 44-116: Headquarters and Headquarters Battery, Anti-Aircraft Artillery Gun Battalion, Semimobile (Washington: U. S. Government Printing Office, 1944), p. 14.

<sup>23</sup> Headquarters Antwerp X, Notes on AAA Radar Operation PAC Defense, 13 January 1945, p. 3. (USACGSC Archives)

<sup>24</sup> War Department, T/O & E 44-27: Antiaircraft Artillery Automatic Weapons Battery, Mobile (Washington: U. S. Government Printing Office, 1944), p. 3; see also War Department, T/O & E 44-127: Anti-aircraft Artillery Automatic Weapons Battery, Semimobile (Washington: U. S. Government Printing Office, 1944), p. 3. (Hereafter referred to as War Department, T/O & E 44-27 and War Department, T/O & E 44-127 respectively.)

<sup>25</sup> War Department, FM 4-102: Employment of Antiaircraft Automatic Weapons (Washington: U. S. Government Printing Office, 1943), p. 12. (Hereafter referred to as War Department, FM 4-102.)

<sup>26</sup> War Department, T/O & E 44-27, op. cit., p. 7; see also War Department, T/O & E 44-127, op. cit., p. 7.

The automatic weapons battalion had four organic firing batteries and a headquarters and headquarters battery.<sup>27</sup> As with the 90mm battalion this organization was for command and tactical control.

The British units employed from time to time in the Antwerp defense were organized differently and had other designations. The basic heavy AA unit was the 3.7 inch gun battery of two troops with four guns in each troop.<sup>28</sup> Each troop had one radar (when possible the U. S. SCR-584) with a spare assigned to each regiment. The U. S. SCR-584 radar with the associated M-9 director was superior to British equipment and efforts were made to equip all antiaircraft units with the U. S. equipment.<sup>29</sup>

The regiment was the counterpart of the U. S. battalion. A British heavy anti-aircraft regiment had three organic batteries giving a total of 24 guns per regiment. This compares with 16 guns in a U. S. 90mm gun battalion.<sup>30</sup>

The British counterpart of the U. S. automatic weapons battalion was the light anti-aircraft regiment of three firing batteries. Each battery was organized with three troops of six 40mm guns.<sup>31</sup> This organization provided 54 40mm guns per regiment as compared with 64 weapons for a U. S. automatic weapons battalion, half of which were 40mm guns and half .50 caliber machine guns.

---

<sup>27</sup> War Department, FM 4-102, op. cit., p. 3.

<sup>28</sup> Major L. F. Ellis, The Battle of Normandy, Vol. I, Victory in the West (London: Her Majesty's Stationery Office, 1962), p. 538.

<sup>29</sup> United States Army Air Defense School, op. cit., p. 100.

<sup>30</sup> Ellis, loc. cit.

<sup>31</sup> Ibid.

The next level of command in the British structure was the brigade. This consisted of two or more heavy and three or more light anti-aircraft regiments.<sup>32</sup> The brigade was the highest level of British antiaircraft organization employed at Antwerp. The U. S. equivalent of the British brigade was the group with the next higher U. S. echelon being the brigade. At times there were up to four U. S. groups and two U. S. brigades employed at Antwerp.<sup>33</sup> Figure 9 shows the typical U. S. antiaircraft organization and Figure 10 shows the typical British organizational structure.

While the U. S. and British organizations were somewhat different, the equipment used by both countries was essentially the same. Both used American SCR-584 radars and M-9 directors. The 40mm Bofors gun was used by U. S. automatic weapons units and British light anti-aircraft batteries.<sup>34</sup> The heavy gun units used different guns but the characteristics of both were very similar.

#### EQUIPMENT

The most numerous weapon in Antwerp's defense was the U. S. 90mm gun. No unanimous opinion is revealed as to which country had the best heavy antiaircraft artillery, but in most discussions the 90mm gun ranks at the top of the list or very near the top. The 90mm gun was accepted by the U. S. Army in 1940. Within two years they were being manufactured at the rate of 2,000 units per month.<sup>35</sup>

<sup>32</sup>Ibid., p. 537.

<sup>33</sup>Antwerp X, Rpt. 2 A, op. cit., pp. 1-2.

<sup>34</sup>John Kirk and Robert Young, Jr., Great Weapons of World War II (New York: Walker and Co., 1961), p. 256.

<sup>35</sup>Ibid., p. 260.

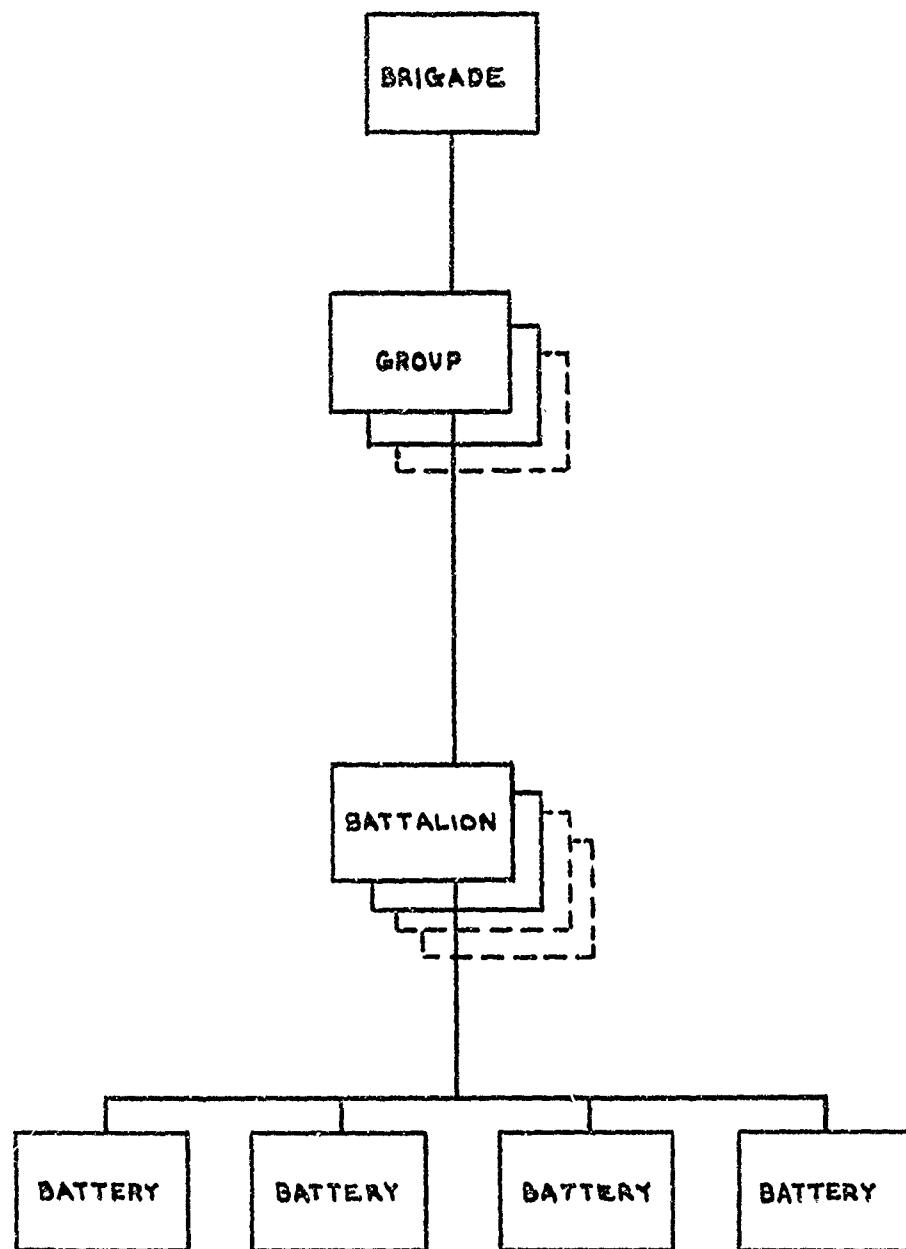


Figure 9. U.S. Antiaircraft Organizational Structure

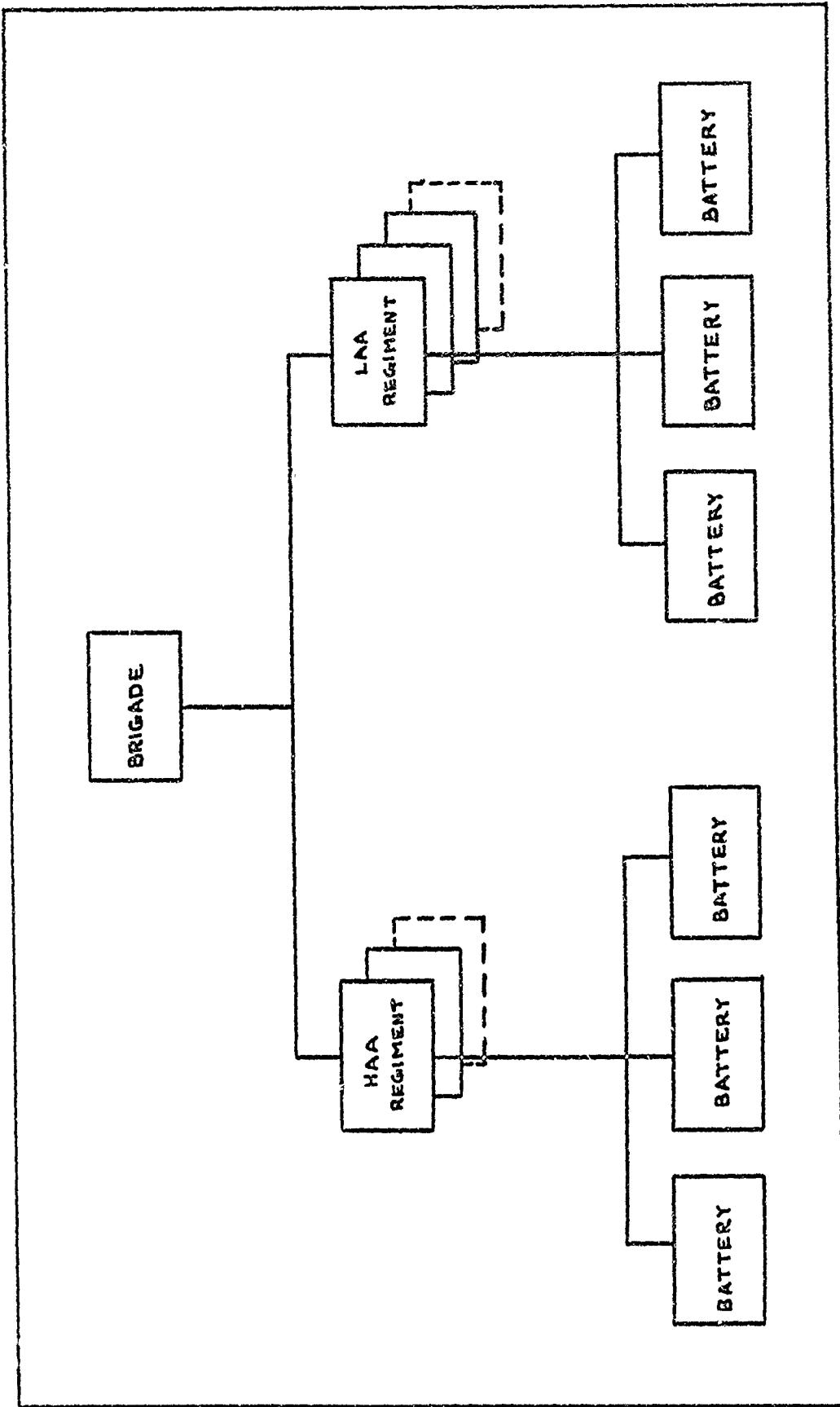


Figure 10. British Antiaircraft Organizational Structure

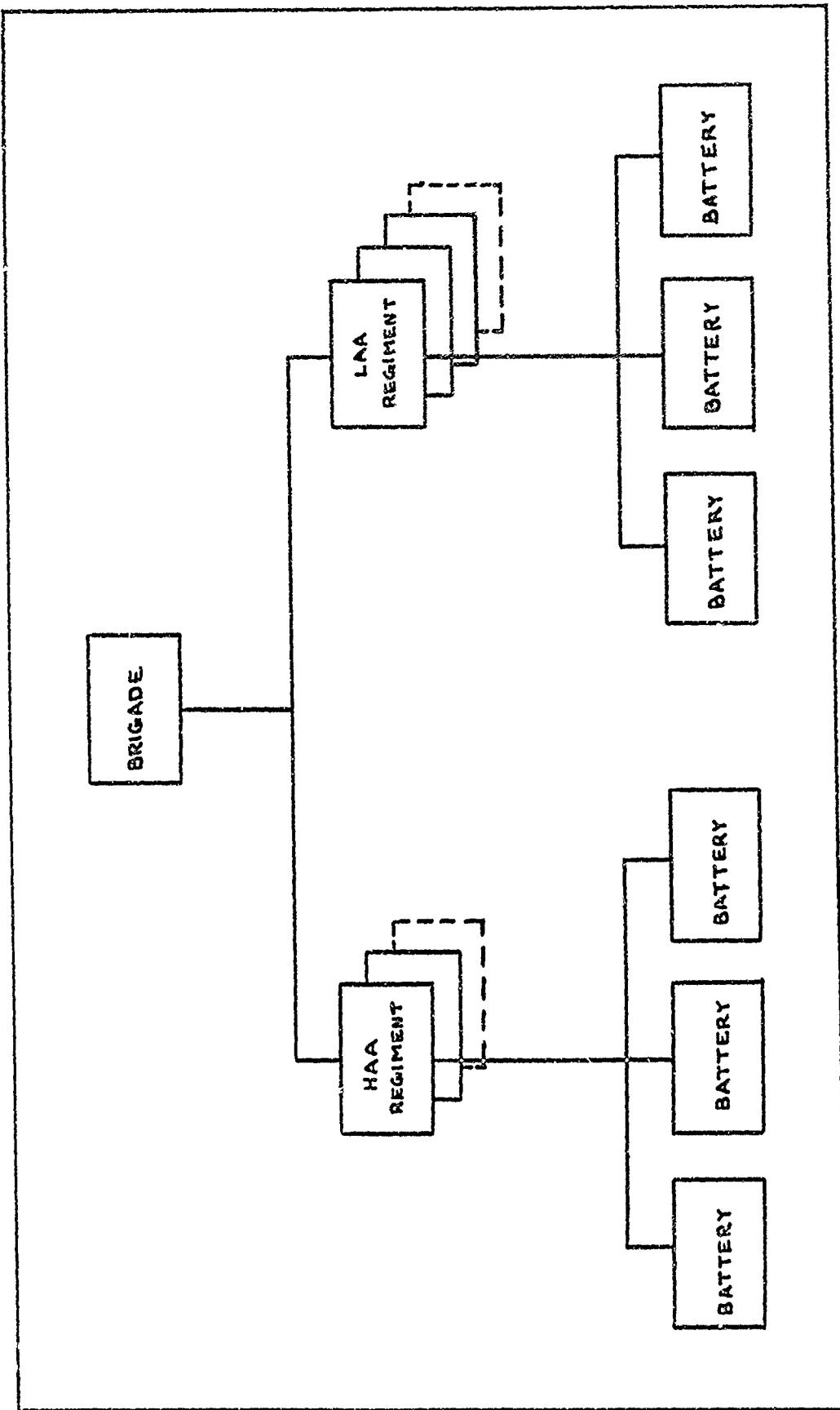


Figure 10. British Antiaircraft Organizational Structure

in Sweden during the early 20's. The gun with its mount was very mobile as it only weighed 5,800 pounds. The 40mm Bofors were clip fed and they fired automatically with a cyclic rate of 120 rounds per minute. Its range was 5,000 yards limited by the self-destruct feature of the tracer ammunition.<sup>40</sup>

The .50 caliber machine guns were effective to a slant range of 500 yards. Each gun could be fired in short bursts at a cyclic rate of 600 rounds per minute.<sup>41</sup> With four guns on a single mount a large volume of fire was possible. These guns were particularly effective against low-flying aircraft but were ineffective against the V-1's which normally approached the defense at altitudes above their maximum range.

The 40mm guns used point detonating ammunition and the .50 caliber machine guns used standard ball ammunition. The 90mm and 3.7 inch guns in Antwerp's defense initially used high explosive ammunition with a mechanical time fuze. These fuzes had to be set prior to firing to detonate the projectile after a precalculated time of flight. Projectile flight time varied in accordance with muzzle velocity, temperature variations, and inaccurate determination of target altitude which caused premature or late bursts. To reduce the inaccuracies associated with the mechanical time fuze a radio proximity fuze was

---

<sup>40</sup>United States Army Air Defense School, op. cit., p. 33; see also Kirk and Young, op. cit., pp. 256-259; see also Melvin M. Johnson and Charles T. Haven, Automatic Weapons of the World (New York: William Morrow and Company, 1945), pp. 328, 542.

<sup>41</sup>War Department, FM 4-102, op. cit., p. 13.

developed and put into use in Antwerp's defense in January 1945.<sup>42</sup> This fuze incorporated a small radio transmitter which put out a continuous signal. When the signal was reflected from the target at the correct amplitude and frequency, the fuze caused the projectile to detonate. If the projectile missed the target by a wide margin, it would continue on a ballistic trajectory for a fixed time and then self-destruct.<sup>43</sup> These fuzes were an important factor in the success of the Antwerp defense.

The primary radar used in the Antwerp defense was the SCR-584. The unit was completely mobile and could be placed in operation within 15 minutes. The radar was capable of detecting a target at 70,000 yards slant range. Terrain characteristics could limit the range of the radar. Searching was accomplished either automatically or manually. Automatic azimuth and elevation tracking was possible out to 32,000 yards. Range tracking was manual. At 28,000 yards the radar could furnish accurate present position data.<sup>44</sup> This information was then sent to the gun director where it was converted into pointing data for the guns.

The M-9 director electronically predicted future target location based on the present position data furnished by the radar. The predicted location was predicated on the assumption that the target would continue on its present course. This location was the basis for computation of firing azimuth, quadrant elevation and fuze setting data which was

---

<sup>42</sup> Headquarters Antwerp X, Report No. 2 G, 1 February 1945, p. 5.

<sup>43</sup> Barnes, op. cit., pp. 85-88.

<sup>44</sup> Department of the Army Field Manual, FM 44-44, Service of Radio Set SCR-584 (Washington: U. S. Government Printing Office, 1949), pp. 3-7. (Hereafter referred to as DA, FM 44-44.)

electrically transmitted to the guns. Integral optical devices could furnish target azimuth and angular elevation present position data if the radar was non-operative. With this mode of operation a stereoscopic height finder was used to determine target range.<sup>45</sup> The latter was unreliable in foul weather.

#### EARLY WARNING

Maximum effectiveness of this equipment could only be realized with timely early warning information on approaching V-1's. Their high speed and low altitude limited the engagement time for a fire unit thereby limiting the total number of rounds that could be fired at any particular target. An extensive network of personnel and communications provided early warning of the approach of V-1's to the fire units.

The heart of this system was the Antiaircraft Operations Room (AAOR). It acted as the focal point of incoming early warning information. During the peak deployment of units defending Antwerp there were two such rooms which were operated by the two brigades commanding the fire units.<sup>46</sup>

The AAOR could be set up in an existing building or could be established in a tent or other temporary shelter. To accomplish the mission of Antwerp X equipment known as the AN/TTQ-1 (Transportable

---

<sup>45</sup> War Department, FM 4-121, op. cit., pp. 8-16; see also DA, FM 44-44, op. cit., p. 42.

<sup>46</sup> Headquarters Antwerp X, AAOR-Organization and Operation, Antwerp X, 8 January 1945, p. 1. (USACGSC Archives)

Filter and Operations Room Unit Assembly) was issued. The AN/TTQ-1 consisted of a large semi-trailer outfitted with tables, chairs, plotting board and assorted communications equipment. This trailer was specifically designed to conduct operations normally executed in the AAOR.

The AAOR crew included one officer and six or more enlisted men. The number of enlisted men varied with the number of early warning sources.<sup>47</sup> The crew's duties were to receive the early warning information, interpret the situation, sort and correlate the overlapping data. Next they broadcast the information to the adjacent AAOR or to the units that could take tactical action.

Air Force commands operating in the area established Sector Area Operations Rooms which generated early warning information. Some of this was furnished to the AAOR's by telephone and radio. Other early warning sources included British operated surveillance radars and ground observers. Eight radars were located in a belt approximately 40 miles in front of the gun defense in January 1945. British ground observers were located about 50 miles in front of the guns with a mission of identifying objects. A secondary network of U. S. observers positioned themselves 15 miles ahead of the gun sites. They communicated directly to the fire units but were also monitored by the AAOR's.<sup>48</sup>

The two AAOR's were connected by wire and radio links with one of the two acting as the central operations facility. The central operations facility in turn disseminated information to the fire units.

---

<sup>47</sup>Ibid., pp. 1-2.

<sup>48</sup>Ibid., pp. 4-5, Annex B.

This arrangement allowed maximum centralized control insuring that each incoming V-1 would be engaged. This plan also facilitated transmission of data from the Antwerp defense to the adjacent Brussels defense without duplication.<sup>49</sup> A schematic representation of the overall system is shown in Figure 11.

From October 1944 to March 30, 1945 the defense completed its mission. Of the 4,883 V-1's detected by the Antwerp defense only 4.5 per cent fell within the designated vital area.<sup>50</sup> This is an outstanding attrition rate and indicates the effectiveness of the organization, tactics, weaponry and manpower used in the port's defense.

---

<sup>49</sup> Ibid., p. 5.

<sup>50</sup> IX ADC, Summary, op. cit., p. 32.

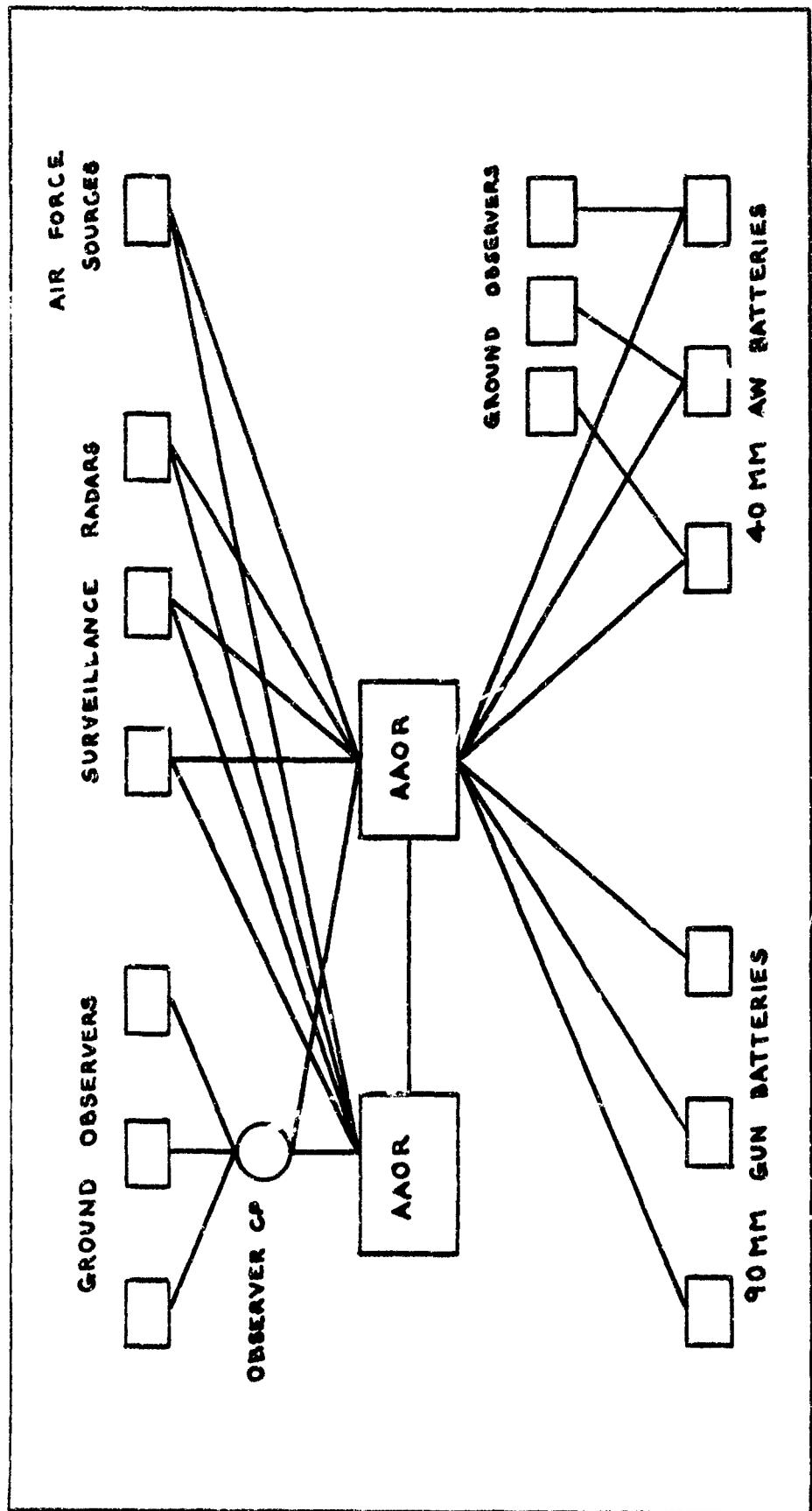


Figure 11. Early Warning Elements and Communications Links 51

51 Headquarters Antwerp X, AAOR-Organization and Operation, Antwerp X, 8 January 1945, Annex B.

## CHAPTER IV

### RESULTS AND ANALYSIS

Air defense engagement functions include: the detection of potential threat objects, the identification of those objects, the interception of the hostile objects, and the destruction of the hostile objects.<sup>1</sup> The perfect performance of each of these tasks is the goal of every defense in active warfare. These operations apply to the defense of Antwerp.

#### DETECTION

The first engagement function to consider is detection. Other engagement functions cannot be accomplished without detection. The Antwerp defense relied on radar and ground observers to detect V-1 missiles.

One method of assessing the effectiveness of the detection function is to compare the number of threat objects launched with the number acknowledged by the defense. An after action report of the German organization responsible for V-1 operations shows a total of 8,696 V-1's launched toward Antwerp from Holland and Germany. The same report shows that 1,000 V-1's "crashed."<sup>2</sup> The source does not, however,

---

<sup>1</sup>Supra, p. 1.

<sup>2</sup>Corps z. V., After Action Report, 8 April 1945, cited by LTC M. C. Helfers, The Employment of V-Weapons by the Germans During World War II (Washington: Department of the Army, Office of the Chief of Military History, n.d.), pp. 91-92.

define the criteria used to categorize a missile as crashed. Probably this category included those missiles that the launch crews saw fall to the ground or explode within sight of the launching facility. The number of V-1's that strayed off course or crashed out of sight of the launching crew and those missiles that did not come within range of the defensive early warning radars is unknown. Hereafter it will be assumed that all V-1's aimed at Antwerp and not listed as crashed actually came within range of the defense's surveillance means. Accordingly it is assumed that 7,687 V-1's approached Antwerp.

The final operations report of Antwerp X shows 4,883 V-1's "launched."<sup>3</sup> The probable source of the Antwerp X figure was the number of radar tracks recorded throughout the duration of the defense. This would equate to the total number of V-1's detected. Thus only 63 per cent of the total number of missiles launched were detected if the foregoing assumptions are correct.

This implies that 37 per cent of the V-1's launched went undetected. While this may have been the case, it does not prove that the detection system of the defense was unsuccessful. The fact that the Germans launched a V-1 toward Antwerp does not mean that the missile ever became a threat to the vital area.

The only known source of information relative to the number of vital area threats is from the Antwerp X after action reports. While the reports do not expand on their source, they probably came from records of the subordinate units and the AAOR's. Thus this data would reflect the number of V-1's detected by the surveillance means of the

---

<sup>3</sup>Headquarters Antwerp X Forward, Report No. 2 J. 1 May 1945, p. 3. (Hereafter referred to as Antwerp X, Rpt. 2 J.) (USACGSC Archives)

defense and would therefore indicate a 100 per cent effectiveness for the function of detection. The number of vital area threat V-1's that actually went undetected will probably never be known.

The mission of the defense was to prevent the fall of V-1's within a specified vital area.<sup>4</sup> Another approach to analyzing the effectiveness of the detection function is to examine the reasons for failure to perform this mission. The number of undetected V-1's that fell within the vital area will show the ineffectiveness of the detection function.

The after action reports show that 211 V-1's fell within the vital area.<sup>5</sup> These represent the failure to perform the specified mission. A breakout of these 211 shows that two passed over the defense at an altitude above the upper limit placed on the guns to protect friendly aircraft. To determine these circumstances the defense had to detect the two V-1's. An additional 17 of the 211 are listed as "Detected but lost in flock or rain clutter, or, friendly plane in the field of fire."<sup>6</sup> Thirty-six are categorized as initial targets from a new direction. These apparently went unengaged, but the fact that they are known to have come from a new direction indicates that they were detected. Finally 156 V-1's are shown as having passed through the defenses.<sup>7</sup> Another source states that these 156 were engaged by

---

<sup>4</sup>Supra., p. 32.

<sup>5</sup>Antwerp X. Rpt. 2 J. op. cit., Annex A.

<sup>6</sup>Headquarters Antwerp X, The Story of Antwerp X (50 AAA Brigade, U. S. Army), pages unnumbered. (USACGSC Library)

<sup>7</sup>Ibid.

50

fire.<sup>8</sup> Engagement by fire presupposes detection.

This analysis demands a conclusion that none of the missiles that landed in the vital area were the result of a failure to detect the threat. V-1's which posed a threat to the defense may have gone undetected but they either fell short of the vital area or passed over it and therefore did not contribute to the inability of the defense to perform its mission.

The V-1 was a difficult radar target. The rated range of the SCR-584 against aircraft was 70,000 yards.<sup>9</sup> The SCR-584 radars in the Antwerp defense were emplaced with a maximum mask of 20 mils wherever possible. Taking into consideration the earth's curvature and a 20 mil radar mask, a target approaching at 3,000 feet altitude would clear the horizon at approximately 45,000 yards.<sup>10</sup> The shorter detection range is attributed to the small physical size of the V-1 and the corresponding small radar return. Additionally at low operating altitudes where the V-1 operated radar ground clutter was significant. Unless ideal conditions prevailed and all precautionary measures were exercised, a V-1 could come within radar range and never be detected.<sup>11</sup>

---

<sup>8</sup>Captain A. R. Dellmeyer, Jr., "Antwerp X," Coast Artillery Journal, LXXXVII (September-October, 1945), pp. 2-7.

<sup>9</sup>Headquarters Antwerp X, Notes on AAA Radar Operation PAC Defense, 13 January 1945, p. 1; see also Headquarters Antwerp X, Operations Memorandum No. 8, 17 November 1944, pp. 1-2, Inclosure 1. (USACGSC Archives)

<sup>10</sup>Lamont V. Blake, Radio Ray (RADAR) Range-Height-Angle Charts (Washington: Naval Research Laboratory, 1967), p. 5.

<sup>11</sup>Headquarters Antwerp X, Notes on AAA Radar Operation PAC Defense, op. cit., pp. 1-2.

The constant juggling of units within the defense also contributed adversely to detection. Until the defense along an avenue of approach was perfected, detection capability was not at its optimum. When the northeast attacks began 18 hours lapsed before fire units were in position to assist in detecting approaching V-1's. During this time ground observer efforts were negated by ground fog that blanketed the area 24 hours a day.<sup>12</sup> Initially detection of V-1 threats from the new direction was accomplished solely by the British early warning radars reporting to the AAOR.

Personnel fatigue also affected all facets of the defense. This problem was recognized in the radar vans and crew members were shifted around to various manning positions every thirty minutes during routine search periods.<sup>13</sup>

During the Ardennes offensive units were taken from the Antwerp defense to reinforce the front-line units.<sup>14</sup> The Antwerp defense was reorganized as quickly as possible. However, the withdrawal of units adversely effected the detection capability of the defense. This action further complicated the problems arising from the developing northeast attacks. At the outset of the northern attacks there was a similar reduction in detection capability. Detection was compounded by an insufficient

---

<sup>12</sup> Headquarters Antwerp X, Report No. 2 C, 22 December 1944, pp. 1-2. (USACGSC Archives)

<sup>13</sup> Headquarters Antwerp X, Notes on AAA Radar Operation PAC Defense, loc. cit.

<sup>14</sup> Antwerp X, Rpt. 2 C, op. cit., p. 2-3.

quantity of ground observers positioned to provide information on approaching V-1's.<sup>15</sup>

The high degree of proficiency in detection is attributable to the following facts. Radar equipment was the newest type available. Maintenance activities carried a high priority and maximum effort was directed toward installation of applicable radar modifications. Judicious siting of radars was also emphasized.<sup>16</sup> Importance was placed on "radar screening" to minimize the effects of ground clutter. The battalion's spare radar was employed to pre-select radar locations. The spare also filled in for battery radars turned off for required maintenance.<sup>17</sup>

Certain characteristics of the V-1 facilitated detection. Since the azimuth of approach was relatively constant the radars could be directed to cover a sector on the mean average azimuth of approach. Also the approach altitude of the V-1's was relatively fixed so the radars could be concentrated on a narrow band in the vertical plane.

#### IDENTIFICATION

Once a threat has been detected the next function of the defense is to identify the threat. During Antwerp's defense identification was probably the easiest of the four engagement tasks performed.

---

<sup>15</sup> Headquarters Antwerp X, Report No. 2 G, 1 February 1945, p. 3.

<sup>16</sup> Headquarters Antwerp X, Operations Memorandum No. 2, 12 November 1944, p. 2; see also Headquarters Antwerp X, Operations Memorandum No. 8, 17 November 1944, pp. 1-2; see also Headquarters Antwerp X, Operations Memorandum No. 39, 2 January 1945, pp. 1-2; see also Headquarters Antwerp X, Notes on AAA Radar Operation PAC Defense, op. cit., pp. 1-4. (All USACGSC Archives)

<sup>17</sup> Headquarters Antwerp X, Notes on AAA Radar Operation PAC Defense, op. cit., pp. 2-3.

The basic problem to be solved to perform this function successfully was to establish the identity of unknown friendly objects and unknown hostile objects. Incorrect identification could have resulted in destruction of friendly aircraft or safe passage for hostile craft.

Available sources do not reveal any instances of engagement of friendly aircraft. While this is not conclusive proof that all friendly aircraft were properly identified, the consequences of misidentification, if any, were not noteworthy.

Of the 211 V-1's that landed in the vital area, the 156 that were engaged but not destroyed were properly identified. The specific reasons stated for the remaining 55 suggest that they were correctly recognized but not engaged for reasons excluding incorrect identification.

The basic problem is identifying friend or foe. The most reliable method of determining friend from foe is to make visual contact with the threat object to establish its identity. This is the only known positive means of determining identity. Electronic means can be compromised or rendered useless by countermeasure techniques. Procedures that restrict certain areas or altitudes to friendly aircraft rely upon complete understanding of the limits of the restricted area by the friendly pilots. Restricted altitudes have the same limitation. These last two procedures also depend on the aircraft being in full operational condition with its instruments functioning properly.

Visual identification also has inherent restrictions. Its effectiveness depends upon the observer's alertness and ability to recognize hundreds of aircraft from many observation angles. This method is further limited to fair weather. Clouds, haze, smoke, rain and

snow limit observation. Glare caused by sunshine can preclude positive identification. Unless artificial light is available darkness limits the capability of an observer.

The mission of Antwerp's defense provides insight into reasons for successful threat identification. The defense was charged with preventing the fall of V-1's within a relatively small well defined area. Any object approaching on a course that would take it outside the defended area could be ignored. Thus the number of objects to be identified was reduced.

The mission initially excluded defense against aircraft. Aircraft engagement was permitted after December 27, 1944, only if the V-1 mission remained primary.<sup>18</sup> The defence therefore was able to concentrate on destroying one type of target thereby simplifying identification.

The V-1 was smaller than any friendly aircraft operating in the area. Furthermore the wingspan of the V-1 was shorter than that of any German aircraft operating over Antwerp. Its overall length was shorter than all German planes except the ME-163B rocket propelled interceptor.<sup>19</sup> This latter aircraft had a limited combat range, therefore, it is doubtful that any of them ever flew near Antwerp.

The side view of the V-1 offered readily identifiable features. The pulse jet "stove pipe" extended rearward beyond the tail assembly. It appeared like a second fuselage smaller in diameter than the main body and about half as long riding "piggy-back" on the basic missile. The

---

<sup>18</sup> Headquarters Antwerp I, Report No. 2 D, 29 December 1944, p. 2. (USACGSC Archives)

<sup>19</sup> Leonard Bridgman (ed.), Jane's All the World's Aircraft 1945-46 (New York: Macmillan Co., 1946), pp. 70-8c, 97c-149c, 197c-315c.

hot burning exhaust gases spewed from the rear of the jet engine leaving a bright streak visible for long distances during hours of darkness. Then too, the engine had a characteristic sound described as "...the sound of a very powerful outboard motor cruising at half throttle."<sup>20</sup>

The V-1's flight pattern provided another clue to its identity. Its average speed placed it in a category with the fastest fighter aircraft. Unlike most aircraft the missile followed a fixed heading at a constant altitude. An object approaching the defense from the direction of known launching sites was immediately suspected. The V-1 threats came from a limited number of directions as the number of launching sites was limited. An object approaching the defense at an altitude between 1,000 and 5,000 feet was equally suspected.

The radar return from a V-1 presented a characteristic "pip" on the indicator scopes.<sup>21</sup> The SCR-584 radar incorporated the electronic Identification Friend or Foe (IFF) equipment, RC-184.<sup>22</sup> Basically the ground portion of the IFF system transmitted a coded challenge signal toward an unknown object. If the unknown object had compatible electronic gear it would automatically transmit a coded reply signal to the ground equipment. The equipment then processed the reply and gave a trace on the radar scope indicating a friendly target. While the

<sup>20</sup> Headquarters Antwerp X, Report No. 1, 14 December 1944, Annex C, p. 1. (Hereafter referred to as Antwerp X, Rep. 1.) (USACGSC Archives)

<sup>21</sup> Headquarters Antwerp X, Operations Memorandum No. 2, 12 November 1944, p. 1. (USACGSC Archives)

<sup>22</sup> Department of the Army Field Manual, FM 44-44, Service of Radio Set SCR-584 (Washington: U. S. Government Printing Office, 1949), pp. 295-313; see also Headquarters IX Air Defense Command, Historical and Statistical Summary, 1 January 1944-1 June 1945, p. 33 (upper photograph). (USACGSC Archives)

system could be countered with the correct type of electronic equipment, the V-1 did not have such equipment. Thus when a V-1 was challenged it could not send a reply. While the absence of a reply was not positive identification, it increased suspicion related to that unknown threat.

Another identification aid utilized but not unique to Antwerp was the use of "Restricted Areas" and "Safe Corridors." Certain geographical areas were denied to friendly aircraft flying below a specified altitude.<sup>23</sup> Targets could be engaged within these areas without positive visual identification. Corridors were established to permit safe passage across these areas. While some aircraft inadvertently violated the restricted areas, the majority avoided them thereby decreasing the number of objects to be identified.

#### INTERCEPTION AND DESTRUCTION

Interception begins when a decision is made to engage a given target. Termination of the intercept function and initiation of the destruction function cannot be determined from the data available. The end of the destruction function is clearly defined statistically by the effect of the engagement on the target and therefore a meaningful assessment of the combined functions is possible.

If a target was engaged and destroyed, both functions were accomplished. There is an analytical problem if the target is not destroyed. The target may have been intercepted but not destroyed. Without interception there cannot be destruction. On the other hand

---

<sup>23</sup>Antwerp I, Rot. 1, op. cit., Part Two, p. 2.

if the target was not intercepted then the destruction effectiveness is not measurable. Accordingly, in this analysis interception and destruction will be considered jointly as it is not practical to separate them.

The percentage of V-1's destroyed of the total number engaged provides a measure of the effectiveness of the defense in interception and destruction. Over the entire period of active defense 2,523 vital area threats were engaged. Of these 1,766 or 70 per cent were destroyed.<sup>24</sup> These results were outstanding when compared to other defenses of that era.

Near the end of World War II there were two active defenses employing equipment similar to that used in Antwerp; these were the defense of the airfields on Okinawa in the Pacific theater and the defense of the Rhine River bridges at Remagen. Both defenses were against manned aircraft and achieved similar results. The Okinawa defense destroyed about 28 per cent of the aircraft attacking installations within the defense. For the entire Ryukyus area the defenses took a toll of just over 30 per cent based on a total of almost 500 aircraft.<sup>25</sup> The Remagen bridgehead defense achieved an attrition rate of 25 per cent based on a similar number of aircraft attacking within the defended area.<sup>26</sup>

---

<sup>24</sup> Antwerp X, Part, 2 J, loc. cit.

<sup>25</sup> General Headquarters, United States Army Forces, Pacific, Antiaircraft Artillery Activities in the Pacific War, n.d., pp. 120, 127-128. (USACGSC Archives)

<sup>26</sup> Mary Catherine Welborn, Over-all Effectiveness of First U. S. Army Antiaircraft Guns Against Tactical Aircraft (Washington: The Johns Hopkins University, Operations Research Office, 1950), p. 5.

Again the characteristics of the V-1 were the most significant factor in accounting for this high percentage of interception and destruction. There were a limited number of V-1 launch facilities and the V-1 was practically unmaneuverable. Antwerp's fire control and weapons were oriented on three basic avenues of approach which permitted a high volume of fire on each incoming V-1 thereby increasing the probability of destruction.

The early warning assets of the defense were also concentrated along the avenues of approach. The amount of early warning provided to the fire units increased their capability to engage at maximum range. This allowed units to fire a maximum number of rounds at an incoming target. Crews were at their firing positions and equipment was checked prior to engagement thereby increasing the possibility of accurate interception. During the initial phase of the defense eight minutes of warning was provided on most of the approaching V-1's.<sup>27</sup> By the end of March 1945 the defense was getting almost nine minutes warning on targets approaching from the Northeast, six minutes notice on Southeast attacks, and four minutes warning for attacks approaching from the North.<sup>28</sup>

This warning time was particularly significant when the average speed of the V-1 (350 mph), average SCR-584 detection range (25,000 yards), and maximum gun range (12,000 yards), are considered. The V-1 traveled from the detection point to maximum gun range in about 1 $\frac{1}{4}$

---

<sup>27</sup>Antwerp X, Rpt. 1, op. cit., Part Two, p. 1.

<sup>28</sup>Headquarters Antwerp X, Report No. 2 I., 3 April 1945, pp. 4-5.  
(Hereafter referred to as Antwerp X, Rpt. 2 I.) (USACGSC Archives)

minutes. To engage at maximum range the gun crew had to fire prior to the time the target reached maximum gun range. This requirement left less than one minute of preparation time.

The SCR-584 radar was capable of determining precise present position data at all hours of the day and night regardless of weather conditions. When coupled with the relatively new M-9 director, more accurate predicted position data was determined than had been possible with older radars and directors used earlier in the war. This equipment performed at peak efficiency against a target which did not maneuver in altitude, speed or direction.

The 40mm gun batteries relied on optical devices to determine target present position data. The linear course of the V-1 permitted accurate determination of present position data. A director very similar to that used with the 90mm guns was used with the 40mm guns. As with the M-9 director predicted target location could be very accurately determined with the precise present position data furnished by the optical tracking equipment.

To assist the units during hours of darkness the British search-lights provided target illumination. These units depended on optical tracking for present position information. Searchlights were pointed toward target locations provided by radar. The non-maneuvering V-1 assisted the searchlight operators in staying on target. Continuous illumination enabled the fire units to track the targets without interruption.

The introduction of the variable time (VT) fuze in January 1945 had an influence on the destruction percentage. Figure 12 shows a steady increase in the percentage of vital area threats destroyed compared with

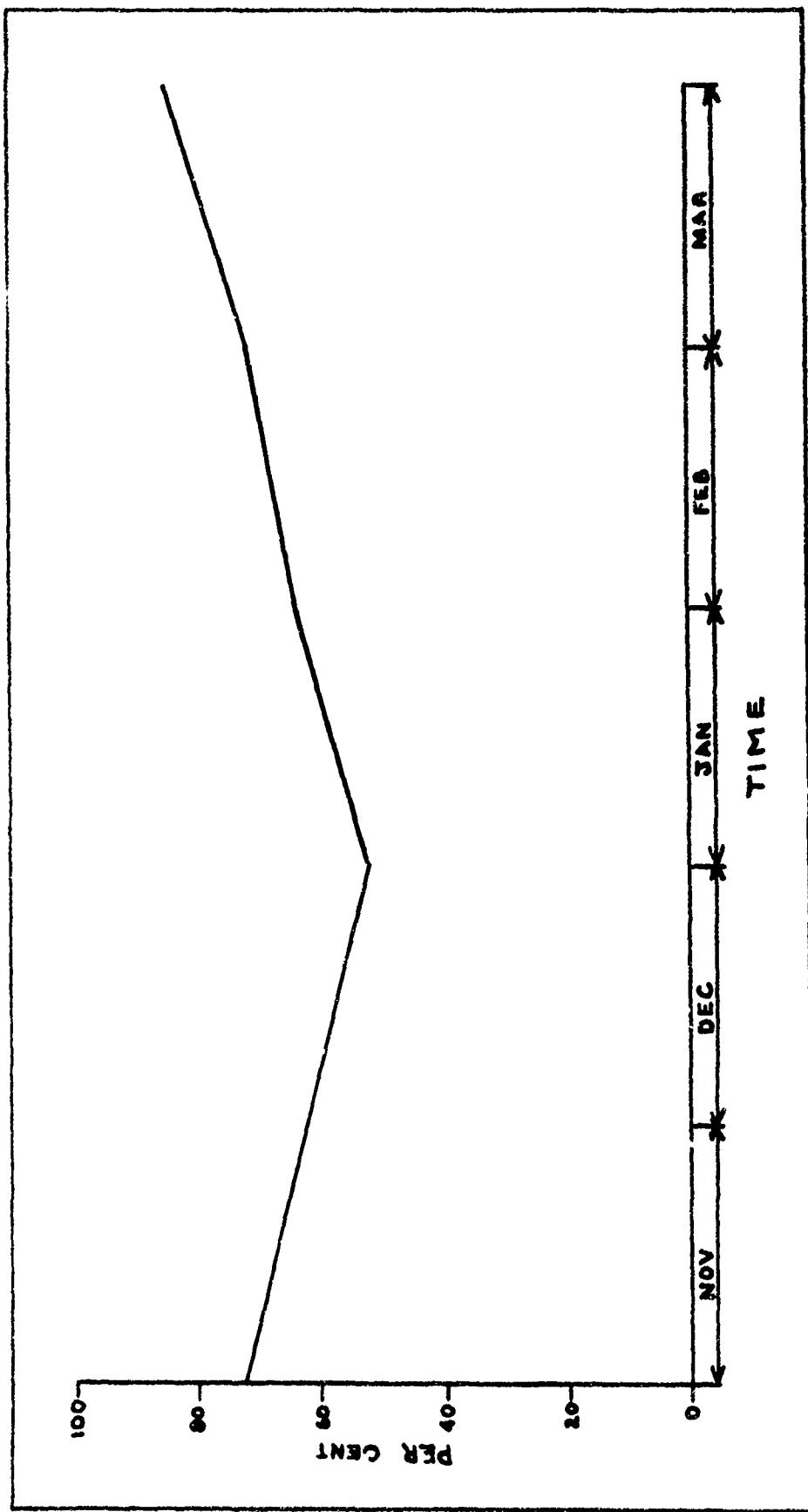


Figure 12. V-1's Destroyed of V-1's Engaged Versus Time<sup>29</sup>

<sup>29</sup> Antwerp X, Rpt. 2 J., loc. cit.

vital area threats engaged for January 1945 and subsequent months. Throughout this period the restrictions on the use of the VT fuzed ammunition were relaxed to permit engagements at progressively lower quadrant elevation angles. Consequently a larger quantity of VT fuzed ammunition was used. Further evidence of the effectiveness of this projectile is seen in Figure 13. The number of rounds of 90mm ammunition expended per V-1 destroyed decreased sharply during the months of February and March 1945. A comparison of Figures 12 and 13 shows that after the introduction of the VT fuze the number of V-1's destroyed increased while the expenditure of ammunition decreased. While improvements in the defensive deployment and better experienced gun crews contributed to this improvement, the most significant factor was the utilization of the VT fuze.

Destruction of a V-1 after interception was complicated as the missile was extremely durable. The V-1 was unlike conventional aircraft as there was no fuel nor any electrical or hydraulic lines in the wings. Shrapnel hitting the wings had little effect on the missile. Also the engine was less vulnerable to shrapnel than an ordinary piston engine. The gyro control devices were less affected by shell bursts than a human pilot. V-1's deflected by shell bursts returned to their original course without apparent damage. Others were turned over by shell bursts. These righted themselves and continued on course.<sup>30</sup>

British experience in the defense of London contributed to the defense of Antwerp. The belt concept for deployment of guns was first used in Phase I of the London defense against V-1's. Figures 4, 5, and 6

---

<sup>30</sup> Headquarters Antwerp X, Report No. 2 E, 5 January 1945, p. 3.  
(USACGSC Archives)

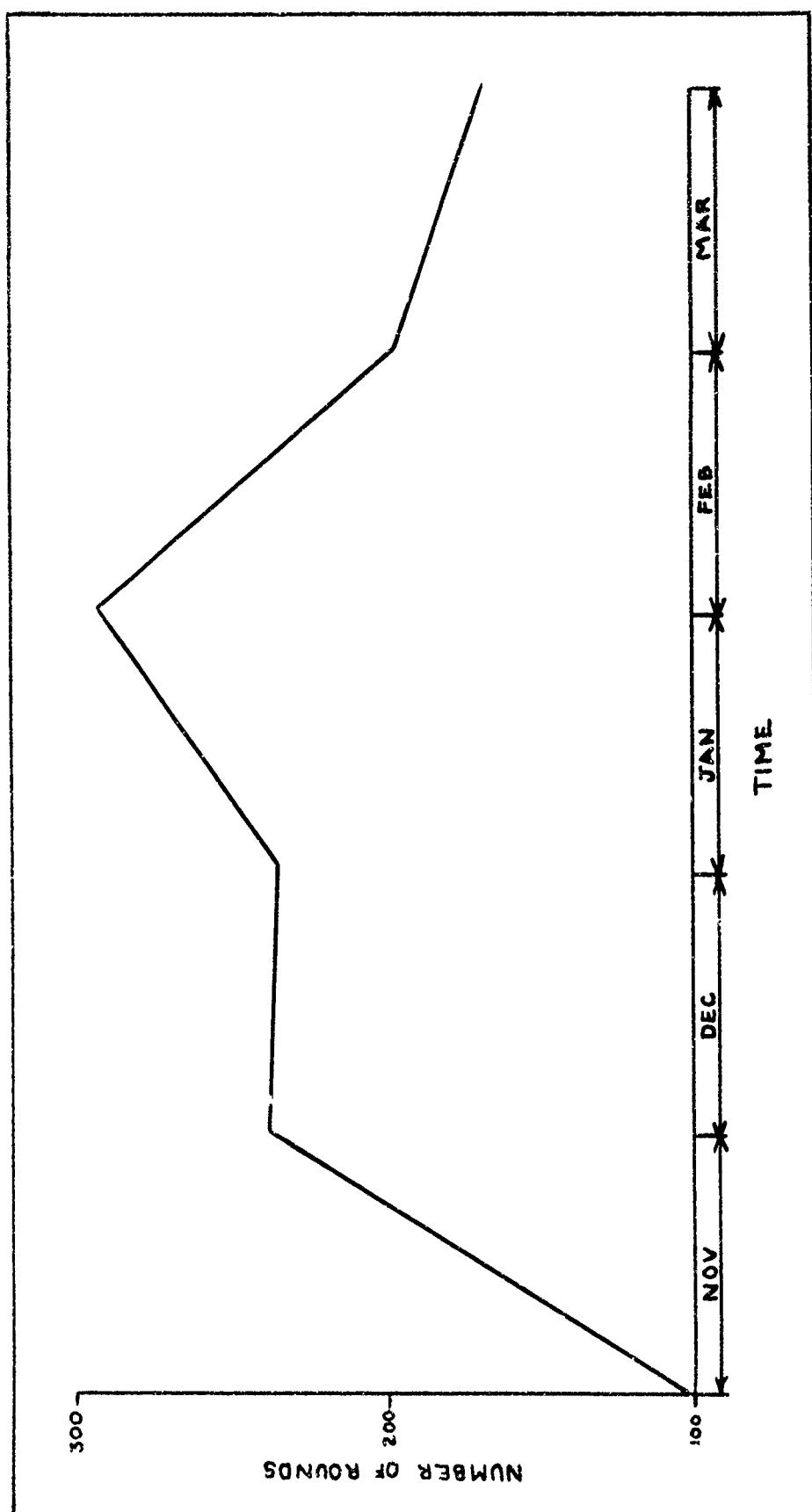


Figure 13. Ammunition Expenditure Versus Time<sup>31</sup>

<sup>31</sup>Antwerp X, Rpt. 2 J., loc. cit.

show examples of how the belt concept was used in defending Antwerp. The gun belts used in the defense of London were about 5,000 yards from front to rear. This created a radar problem with shell bursts from the rear guns cluttering the fire control radars of the forward guns. To prevent this problem the Antwerp defense was established with relatively narrow gun belts separated in depth to provide a "flak free" zone between each belt of at least 3,000 yards.<sup>32</sup> Bursts from the rear guns were behind the zone of action of the forward guns. This reduced the target tracking problem and contributed to the effectiveness of interception.

To realize the benefits of experience, the defense planners initially requested specific gun battalions that had participated in the V-1 defense of London.<sup>33</sup> Two such units were provided and remained in the defense throughout its duration. General information and procedural instructions provided to the first units deployed in the Antwerp defense were direct extracts of similar documents developed in the defense of London. The intercept phase realized the greatest benefit from experience of the four engagement functions of air defense. The proficiency of the fire control equipment operators and gun crews was a critical factor affecting firing accuracy. As with any acquired skill crew proficiency was enhanced by experience.

Another factor affecting interception and destruction was the number of guns in the defense. Figure 14 reflects the number of fire

---

<sup>32</sup> Headquarters Antwerp X, Report No. 2 F, 12 January 1945, Annex D, p. 1. (USACGSC Archives)

<sup>33</sup> Antwerp X, Rpt. 1, op. cit., p. 2.

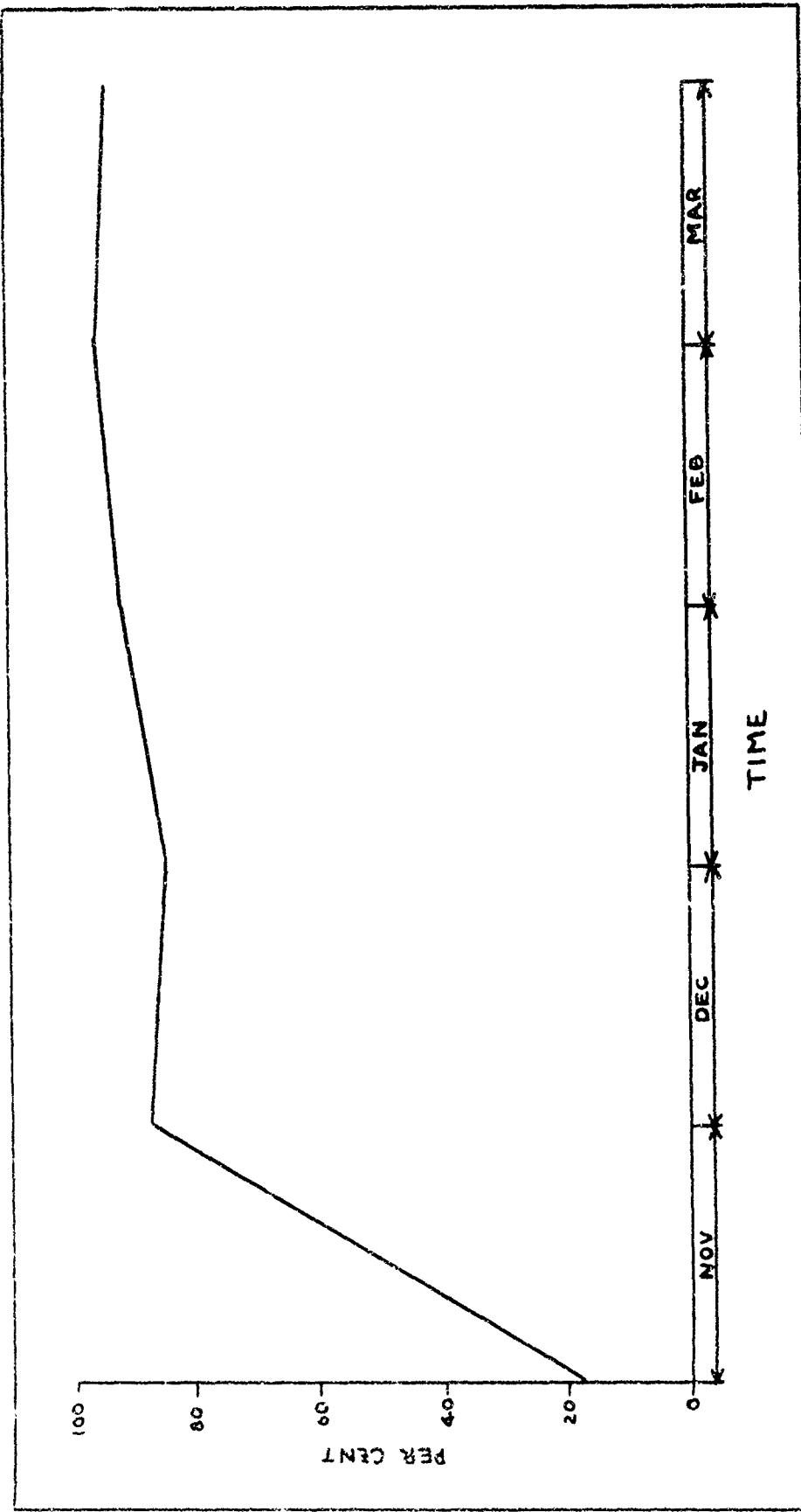


Figure 14. VA Threats Engaged of VA Threats Detected Versus Time

<sup>34</sup> Antwerp X, Rpt. 2 J, loc. cit.

units available to the defense as a function of the number of vital area threats engaged. As additional units were added an increased number of V-1's were engaged. This trend is shown in November 1944. When the Ardennes offensive required the withdrawal of some units from the Antwerp defense in December 1944 the number of threats engaged decreased. In January additional units were brought into the defense and the number of engaged threats again increased. Other factors influenced the number of V-1's engaged. The volume of threats affected the number of V-1's engaged as did the weather and changes in the rules of engagement for the fire units.

The impact on interception and destruction of the number of fire units and the number of threats is also seen in Figure 12. During the month of December when units were withdrawn and the northeast attacks began the number of V-1's destroyed decreased. A similar decrease in November may have been due to the arrival of inexperienced units in the defense. This decrease may be a statistical illusion, however, since the first point on the graph for November represents a percentage based on only five vital area threats destroyed of seven engaged. This is too small a sampling for valid statistical analysis.

Maintenance, training and daily operations were continually stressed to constantly upgrade the state of preparedness. Fire control instruction teams were established to visit fire units. Their mission was to seek areas where improvement was needed and then to instruct unit personnel in proper corrective measures and preventive procedures.<sup>35</sup> Periodic conferences were held to exchange ideas and

---

<sup>35</sup>Antwerp X, Rpt. 2 A, op. cit., p. 5.

to discuss current technical problems.<sup>36</sup> These efforts improved all four engagement functions particularly interception (gunnery accuracy).

The degree of proficiency achieved in interception and destruction is exemplified by the results of the final nine days of the Antwerp defense. During this period 96 of 98 vital area threats were destroyed.<sup>37</sup> This represented an attrition rate "...considerably higher than [had] been achieved ever before."<sup>38</sup>

---

<sup>36</sup> Ibid.

<sup>37</sup> Antwerp I, Rpt. 2 I, op. cit., Annex D, E, F.

<sup>38</sup> Antwerp I, Rpt. 2 J, op. cit., Annex C.

## CHAPTER V

### SUMMARY AND CONCLUSIONS

On June 13, 1944, the Germans introduced a new weapon, the V-1. The V-1 is a jet propelled robot missile which carries almost 2,000 pounds of high explosive. London was the target of initial attacks. The British were not unprepared, however. For months the British had been trying to prevent the Germans from using their newly developed flying bomb, but they were unsuccessful in destroying the launch complexes and supply installations. Now the British were confronted with the problem of terminal defense of London.

The number of attacks increased as the defense expanded. Shortcomings of the defense soon became apparent and adjustments were made to eliminate most of the weaknesses. The degree of success of the defense as measured by the number of V-1's destroyed, increased. European ground action temporarily stopped the attack launched from sites in France.

The battle was not over, however, as the Germans continued with an air launched attack. Technical difficulties of this mode of launching and the growing shortage of aircraft capable of launching V-1 missiles made this phase less effective from the German viewpoint. The volume of V-1's appearing over England decreased and the accuracy of the attacks was poorer than the previous attacks from ground launchers in France.

The defense increased its efficiency with the introduction of U. S. radar equipment and proximity fuzes. This increase in effectiveness was offset, however, by the new dimension of the aerial launch platform. Missiles were no longer limited to a narrow corridor of approach to London and the defense had to be altered to counter this new variable.

As the Germans fell back toward the homeland the front was temporarily stabilized and new ground launching facilities oriented toward London were constructed in Holland. The distance from these new facilities to London was greater than the distance from the earlier French sites. This required a modified missile with less destructive power and inferior accuracy when compared to the earlier models.

The defense met these new attacks with previously proven tactics and renewed determination. The British defeated this effort destroying over 90 of 124 V-1's launched from these new positions.

Shortly after the V-1 launch facilities in France were overrun the port of Antwerp, Belgium, was captured intact by the Allies. Difficulties relative to logistics operations were suddenly overcome. Antwerp provided ample port facilities for further ground operations into the German homeland. The significance of this development was quickly diagnosed by the Germans. They immediately began preparations to attack Antwerp with the V-1.

The Allies were aware of their good fortune and would not allow the Germans to interfere with their plans for Antwerp. Accordingly a defense against the V-1 was established in October 1944. Planners of Antwerp's defense used experiences of the British in the defense

of London. Defensive aircraft were not used. The tactical deployment of defensive elements was a direct application of British techniques. The equipment that had proven most satisfactory in the London defense was similarly employed in Antwerp's defense. During the early planning phases requests were made to obtain the units which had participated in the London defense. These units added an important expertise to the Allied effort.

The attack against Antwerp developed in three phases corresponding to directions of approach of V-1 missiles headed for the port. The defense adjusted to the changes in direction of the attacks using similar deployment patterns in each new area. The proximity of Antwerp to German held territory permitted the Germans to utilize ground launching facilities throughout the duration of their attacks.

The VT fuze played an important role in the Antwerp defense. It was not used during the early months of the defense for fear that if an unexploded round fell into German hands the security of an important technical development would be compromised. When the VT fuze was introduced the defense effectiveness increased significantly.

The effectiveness of Antwerp's defense is reflected in the statistical records of the defense. Of 4,883 V-1's detected in the vicinity of Antwerp, 2,759 were regarded as threats to the designated vital area. Some of these were not engaged because of procedural restrictions or technical difficulties. A total of 2,523 of the vital area threats were engaged and 1,766 or 70 per cent of them were destroyed.

Only 211 of the 4,883 V-1's operating in the Antwerp area during the defensive period from October 24, 1944, to March 30, 1945, fell within the designated vital area. A similar quantity of high explosive

bombs were dropped on Berlin in a period of three minutes. Throughout the duration of the defense supplies moved through the port without a single day of work being lost.<sup>1</sup> The total dollar value of the damage achieved by the 211 was estimated to be about \$10,000.<sup>2</sup>

The degree of success in Antwerp's defense was primarily attributed to the characteristics of the threat. The fact that the V-1 was unmaneuverable after launch allowed the defense to very accurately predict the target's location. This greatly reduced the interception problem allowing a high percentage of destruction. Since the V-1 could not be maneuvered after launch it was easy to determine an axis of approach and deploy the defensive assets along the axis. This facilitated bringing the maximum amount of firepower to bear on each incoming V-1.

V-1 characteristics also aided the detection and identification processes. The limited number of approach azimuths reduced the volume of air space that had to be continually searched for possible vital area threats. The characteristic altitude, speed and unvarying course made each approaching V-1 immediately suspected. The radar "signature" of the missile assisted the identification procedure. When visual recognition was required the V-1 was readily identifiable.

The physical characteristics of the V-1 reduced its vulnerability to the effects of gunfire. The simple systems of flight-control and propulsion permitted rugged construction less vulnerable to antiaircraft

---

<sup>1</sup> Headquarters Antwerp X, The Story of Antwerp X (50 AAA Brigade, U. S. Army, n.d.), unnumbered pages. (USACGSC Archives)

<sup>2</sup> Headquarters IX Air Defense Command, Historical and Statistical Summary, 1 January 1944-1 June 1945, p. 32. (USACGSC Archives)

fire than the typical conventional aircraft. While the 90mm and 3.7 inch projectiles proved equal to the task of destruction, the 40mm projectiles contained an insufficient explosive charge to develop the explosive force required to destroy or force the V-1 off its preset course.<sup>3</sup>

In late January 1945 the effectiveness of the defense was increased with the introduction of the VT fuze for the 90mm projectiles. An indicator of this improved performance is the increased number of V-1's destroyed of the number engaged for the last two months of the defense. With the use of the VT fuze there was a noticeable decrease in ammunition expenditure per V-1 destroyed.

The British experience with the V-1 provided useful techniques to Antwerp's defenders. Radar siting practices in Antwerp's defense were a direct application of lessons learned in London's defense. The defensive gun belts were designed as a result of methods found most suitable in Great Britain. Coordination between interceptor aircraft and antiaircraft artillery were unworkable in London's defense. This led to the composition of Antwerp's defense which consisted of only antiaircraft artillery with large areas denied to aircraft. The identification process was greatly aided by this practice.

Interception and destruction were the most difficult engagement functions in Antwerp's defense. Separation of these two functions is not practical in an analysis of the available data. If properly placed with respect to the target, the 90mm projectile proved capable of

---

<sup>3</sup> Headquarters United States Forces European Theater, Report of the General Board, Study 38, [n.d.], p. 40. (USACGSC Archives)

destroying the target. This suggests that interception was the function which precluded a greater degree of overall defense effectiveness.

There are similarities between the V-1 missile and present day ballistic missiles. Non-maneuverability after launch is an example. As the V-1 flew at a fixed altitude modern ballistic missiles vary their altitude according to fixed physical laws. The identification problems of the V-1 are basically comparable to the discrimination problems associated with ballistic missiles. While the V-1 identification problem was distinguishing friend from foe, the ballistic missile identification concern is determining whether the incoming threat object is actually a warhead, part of a booster vehicle, or a decoy.

The defense against the V-1 missile proved the validity of a defense in depth with "quiet" zones between defensive echelons. While defensive depth in the horizontal dimension may be less important in solving the ballistic missile intercept problem, it appears that defensive depth in altitude is significant. These similarities suggest areas for additional study.

Of all the antiaircraft defenses of World War II the defense of Antwerp, Belgium, stands as a tribute to the men involved and the effectiveness of their equipment. This is expressed in an excerpt from a letter to the commander of Antwerp X from the Commanding General of General Headquarters AA Troops, 21 Army Group:

This is a great victory; perhaps not heralded or understood by the world at large in the same way as they would appreciate a victory by other arms. The victories of other arms have territorial gains to show. You have not, but nevertheless this does not make it less important than any other form of major military success in its effect on the final outcome of the war. It has been a perfect example of technical and tactical skill assisted by the harmonious co-operation by all ranks of both

nations, commanded by yourself.<sup>4</sup>

---

<sup>4</sup>Major General W. R. Revell-Smith, GOC's Memorandum, 21 Army Group, GHQ AA Troops, reproduced in Antwerp X, Rpt. 2J, op. cit., Annex D.

## **BIBLIOGRAPHY**

## BIBLIOGRAPHY

### BOOKS

Barnes, G. M. Weapons of World War II. New York: D. Van Nostrand Co., 1947.

Blumenson, Martin (ed.). Breakout and Pursuit. U. S. Army in World War II: European Theater of Operations. Washington: U. S. Department of the Army, Office of the Chief of Military History, 1962.

Bridgman, Leonard (ed.). Jane's All the World's Aircraft, 1945-46. New York: Macmillan Co., 1946.

Cole, Hugh M. United States Army in World War II, the European Theater of Operations, the Ardennes: Battle of the Bulge. Washington: Department of the Army, Office of the Chief of Military History, 1965.

Collier, Basil. The Battle of the V-Weapons 1944-45. New York: William Morrow & Company, 1965.

\_\_\_\_\_. The Defence of the United Kingdom. London: Her Majesty's Stationery Office, 1957.

Eisenhower, Dwight D. Crusade in Europe. New York: Doubleday & Company, Inc., 1948.

\_\_\_\_\_. Report by the Supreme Commander to the Combined Chiefs of Staff on the Operations in Europe of the Allied Expeditionary Force, 6 June 1944 to 3 May 1945. Washington: U. S. Government Printing Office, 1946.

Ellis, Major L. F., and others. The Battle of Normandy. Vol. I, Victory in the West. London: Her Majesty's Stationery Office, 1962.

Johnson, Melvin M., Jr., and Charles T. Haven. Automatic Weapons of the World. New York: William Morrow and Company, 1945.

Kirk, John, and Robert Young, Jr. Great Weapons of World War II. New York: Walker and Company, 1961.

Lessner, Erwin Christian. "World War II," Encyclopedia Americana, 1956, XXIX, 556a-560.

Montgomery, Gernard Law. The Memoirs of Field-Marshal The Viscount Montgomery of Alamein, K. G. Cleveland: The World Publishing Company, 1958.

Newman, James R. The Tools of War. New York: Doubleday, Doran & Co., 1943.

Pile, Frederick A. Ack-Ack. London: George G. Harrap and Co., Ltd., 1949.

Pocock, Rowland F. German Guided Missiles of the Second World War. New York: Arco Publishing Company, Inc., 1967.

Kupperthal, Roland G. United States Army in World War II, the European Theater of Operations, Logistical Support of the Armies. Vol. I, May 1941-September 1944. Washington: Department of the Army, Office of the Chief of Military History, 1953.

. United States Army in World War II, the European Theater of Operations, Logistical Support of the Armies. Vol. II, September 1944-May 1945. Washington: Department of the Army, Office of the Chief of Military History, 1959.

#### PERIODICALS

Badger, Brigadier General George M. "Some Sidelights on Antwerp X," Coast Artillery Journal, LXXXVIII (September-October, 1945), 11-13.

Dallmeyer, Captain A. R., Jr. "Antwerp X," Coast Artillery Journal, LXXXVIII (September-October, 1945), 2-7.

Montgomery, Field Marshal The Viscount Montgomery of Alamein. "Operations In North-West Europe from 6th June, 1944 to 5th May, 1945," The London Gazette, Supplement, September 4, 1946.

Phorkelson, William L. "Activities of the IX Air Defense Command," Antiaircraft Journal, LXXXII (March-April, 1949), 2-8.

Watkins, Major E. S. "Secret Phase of the Flying Bomb," Coast Artillery Journal, LXXXVIII (September-October, 1945), 43-46.

#### PUBLIC DOCUMENTS

Department of the Army. FM 44-44: Service of Radio Set SCR-584. Washington: U. S. Government Printing Office, October 1949.

War Department. FM 4-100: Organization and Tactics of Antiaircraft Artillery. Washington: U. S. Government Printing Office, June 1943.

War Department. FM 4-102: Employment of Antiaircraft Automatic Weapons. Washington: U. S. Government Printing Office, August 1943.

War Department. FM 4-104: Employment of Antiaircraft Guns. Washington: U. S. Government Printing Office, June 1943.

War Department. FM 4-110: Antiaircraft Artillery Gunnery. Washington: U. S. Government Printing Office, September 1943.

War Department. FM 4-121: Fire Control, Guns. U. S. Government Printing Office, December 1943.

War Department. T/O & E 44-27: Antiaircraft Artillery Automatic Weapons Battery, Mobile. Washington: U. S. Government Printing Office, 1944.

War Department. T/O & E 44-116: Headquarters and Headquarters Battery, Anti-Aircraft Artillery Gun Battalion, Semimobile. Washington: U. S. Government Printing Office, 1944.

War Department. T/O & E 44-127: Antiaircraft Artillery Automatic Weapons Battery, Semimobile. Washington: U. S. Government Printing Office, 1944.

#### UNPUBLISHED DOCUMENTS\*

Army Service Forces. Salvo Firing at Buzz Bombs with 90mm AA Guns.  
14 March 1945.

Blake, Lamont V. Radio Ray (RADAR) Range-Height-Angle Charts. Washington: Naval Research Laboratory, 1968.

Cibula, Lt. Col. Alvin M. Antiaircraft Command and Center Study No. 26.  
Historical Section, Army Ground Forces, 1946.

General Headquarters, U. S. Army Forces, Pacific. Antiaircraft Artillery Activities in the Pacific War. [n.d.]

Headquarters Antwerp X. AAOR-Organization and Operation, Antwerp X.  
8 January 1945.

- \_\_\_\_\_. Notes on AAA Radar Operation PAC Defense. 13 January 1945.
- \_\_\_\_\_. Operations Memorandum No. 2. 12 November 1944.
- \_\_\_\_\_. Operations Memorandum No. 8. 17 November 1944.
- \_\_\_\_\_. Operations Memorandum No. 27. 3 December 1944.
- \_\_\_\_\_. Operations Memorandum No. 39. 2 January 1945.

\*Documents in this category are located in U. S. Army Command and General Staff College Library or Archives.

- \_\_\_\_\_. Operations Memorandum No. 40. 11 January 1945.
- \_\_\_\_\_. Operations Memorandum No. 46. 25 January 1945.
- \_\_\_\_\_. Operations Memorandum No. 47. 27 January 1945.
- \_\_\_\_\_. Operations Memorandum No. 48. 2 February 1945.
- \_\_\_\_\_. Operations Memorandum No. 48, Change No. 1. 20 February 1945.
- \_\_\_\_\_. Operations Memorandum No. 48, Change No. 2. 15 March 1945.
- \_\_\_\_\_. Operations Memorandum No. 48, Change No. 3. 28 March 1945.
- \_\_\_\_\_. Operations Memorandum No. 52. 7 March 1945.
- \_\_\_\_\_. Operations Memorandum No. 53. 11 March 1945.
- \_\_\_\_\_. Operations Memorandum No. 57. 28 March 1945.
- \_\_\_\_\_. Operations Memorandum No. 58. 5 April 1945.
- \_\_\_\_\_. Radar Screening Lox Flying Targets. 13 January 1945.
- \_\_\_\_\_. Report No. 1. 14 December 1944.
- \_\_\_\_\_. Report No. 2 A. 6 December 1944.
- \_\_\_\_\_. Report No. 2 B. 14 December 1944.
- \_\_\_\_\_. Report No. 2 C. 22 December 1944.
- \_\_\_\_\_. Report No. 2 D. 29 December 1944.
- \_\_\_\_\_. Report No. 2 E. 5 January 1945.
- \_\_\_\_\_. Report No. 2 F. 12 January 1945.
- \_\_\_\_\_. Report No. 2 G. 1 February 1945.
- \_\_\_\_\_. Report No. 2 H. 4 March 1945.
- \_\_\_\_\_. Report No. 2 I. 3 April 1945.
- \_\_\_\_\_. The Story of Antwerp X. 50 AAA Brigade, U. S. Army, [n.d.]

Headquarters Antwerp X Forward. Report No. 2 J. 1 May 1945.

Headquarters Army Ground Forces. Report of Visit to European Theater,  
16 September-20 October 1944. 28 October 1944.

Headquarters European Theater of Operations. Anti-Aircraft Artillery Notes, Number 19. 28 February 1945.

- \_\_\_\_\_. Anti-Aircraft Artillery Notes, Number 8. 13 December 1944.
- \_\_\_\_\_. Anti-Aircraft Artillery Notes, Number 25. 11 April 1945.
- \_\_\_\_\_. Anti-Aircraft Artillery Notes, Number 33. 6 June 1945.
- \_\_\_\_\_. Anti-Aircraft Artillery Notes, Number 34. 20 June 1945.
- \_\_\_\_\_. Anti-Aircraft Artillery Notes, Number 14. 24 January 1945.

Headquarters 14th Antiaircraft Command. Monthly Summary of Friendly Intelligence. 15 January 1945.

Headquarters IX Air Defense Command. Historical and Statistical Summary, 1 January 1944-1 June 1945. [n.d.]

- \_\_\_\_\_. Operations Intelligence Summary, Number 44. 24 February 1945.
- \_\_\_\_\_. Operations Intelligence Summary, Number 45. 3 March 1945.
- \_\_\_\_\_. Operations Intelligence Summary, Number 46. 10 March 1945.
- \_\_\_\_\_. Operations Intelligence Summary, Number 47. 17 March 1945.
- \_\_\_\_\_. Operations Intelligence Summary, Number 48. 24 March 1945.
- \_\_\_\_\_. Operations Intelligence Summary, Number 49. 29 March 1945.
- \_\_\_\_\_. Operations Intelligence Summary, Number 50. 6 April 1945.
- \_\_\_\_\_. Operations Intelligence Summary, Number 51. 13 April 1945.
- \_\_\_\_\_. Operations Intelligence Summary, Number 52. 20 April 1945.
- \_\_\_\_\_. Operations Intelligence Summary, Number 53. 27 April 1945.
- \_\_\_\_\_. Operations Intelligence Summary, Number 54. 4 May 1945.
- \_\_\_\_\_. Operations Intelligence Summary, Number 55. 10 May 1945.

Headquarters United States Forces European Theater. Report of the General Board, Study 38. [n.d.]

Helpers, M. C. The Employment of V-Weapons by the Germans During World War II. Washington: Department of the Army, Office of the Chief of Military History, 1954.

U. S. Army Air Defense School. Air Defense, An Historical Analysis.  
4 vols. Ft. Bliss, Texas: U. S. Army Air Defense School, June 1965.

Welborn, Mary Catherine. Over-All Effectiveness of First U. S. Army  
Antiaircraft Guns Against Tactical Aircraft. Technical Memorandum  
ORO-T-42. Washington: Operations Research Office, The Johns Hopkins  
University, 1950.

\_\_\_\_\_. V-1 and V-2 Attacks Against the United Kingdom During World  
War II. Technical Memorandum ORO-T-45. Washington: Operations  
Research Office, The Johns Hopkins University, 1950.